# SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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APRIL, 1955—VOL. 27, No. 4

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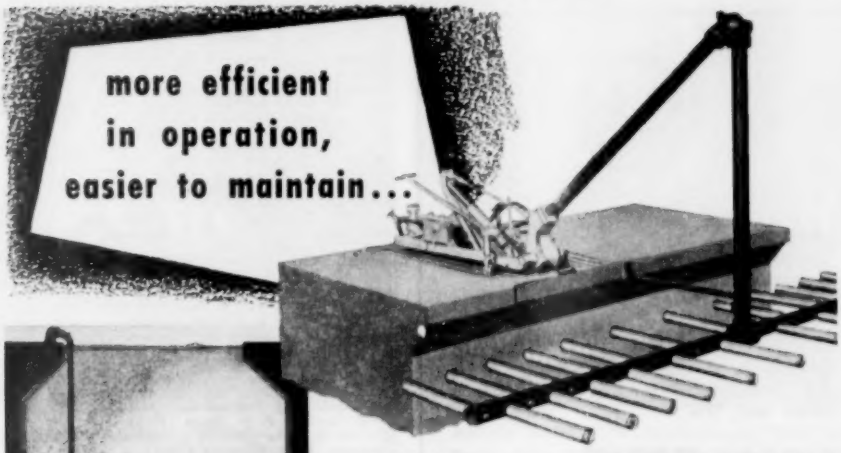


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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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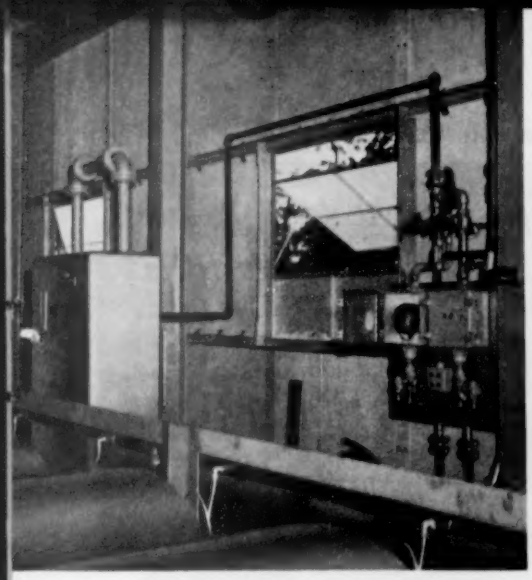
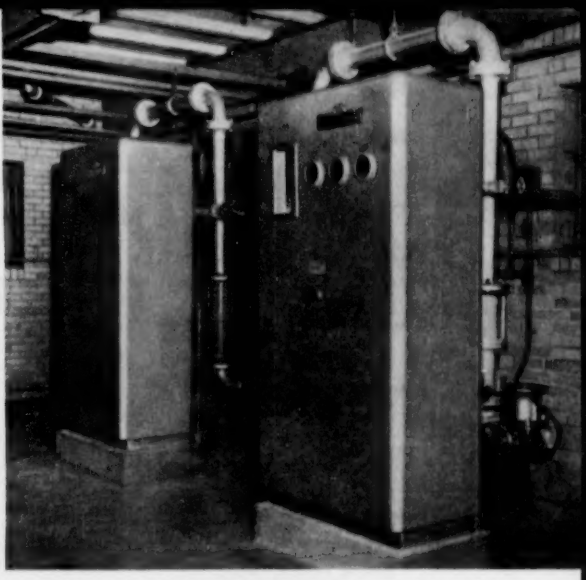


One of the two temporary chlorinating stations which served the Blackstone Valley Sewer District during the interim disinfection period. One of the Builders Chlorinizers can be seen in the background.



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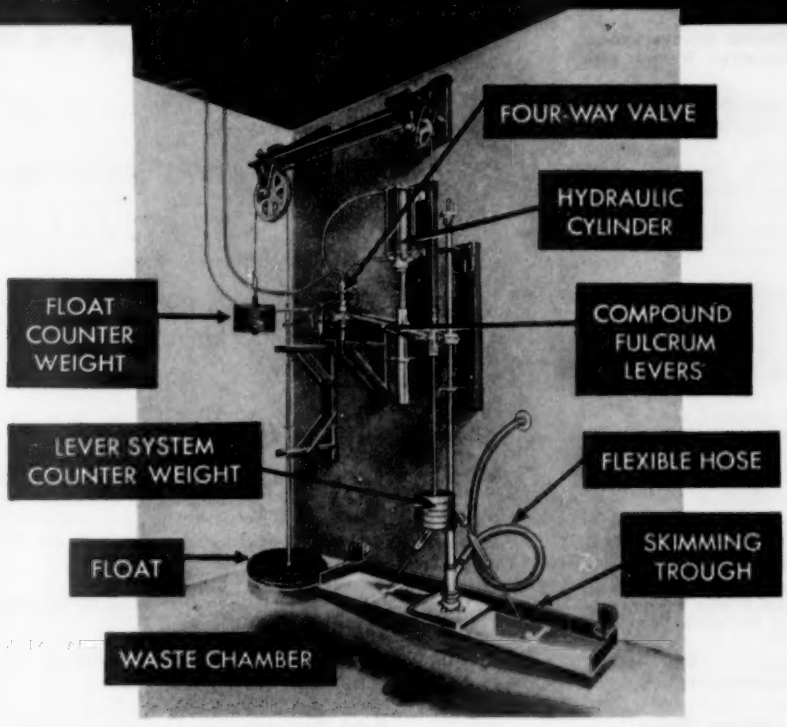


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| Maryland-Delaware Water and Sewerage Assn. | Commander Hotel, Ocean City, Md. | May 25–27, 1955 |
| Alabama Water and Sewage Assn. | Univ. of Alabama, Tuscaloosa, Ala. | June 6–8, 1955 |
| New York Sewage and Industrial Wastes Assn. | Hotel Ten Eyck, Albany, N. Y. | June 13–14, 1955 |
| New England Sewage and Industrial Wastes Assn. | Hotel Ten Eyck, Albany, N. Y. | June 13–14, 1955 |
| Institute of Sewage Purification | Brighton, England | June 13–17, 1955 |
| Ohio Sewage and Industrial Wastes Treatment Conf. | Deshler-Hilton Hotel Columbus, Ohio | June 23–24, 1955 |
| Central States Sewage and Industrial Wastes Assn. | Kahler Hotel, Rochester, Minn. | June 22–24, 1955 |
| Pennsylvania Sewage and Industrial Wastes Assn. | Penna. State Univ. State College, Pa. | Aug. 22–24, 1955 |
| Iowa Sewage Works Assn. | Hotel Waukonsa Fort Dodge, Iowa | Sept. 7–9, 1955 |
| Kentucky-Tennessee Industrial Wastes and Sewage Works Assn. | Phoenix Hotel Lexington, Ky. | Sept. 12–14, 1955 |
| Georgia Water and Sewage Assn. | Georgia Inst. Tech., Atlanta, Ga. | Sept. 21–23, 1955 |
| South Dakota Water and Sewage Works Conf. | Brown Palace Hotel, Mobridge, S. Dak. | Sept. 21–23, 1955 |

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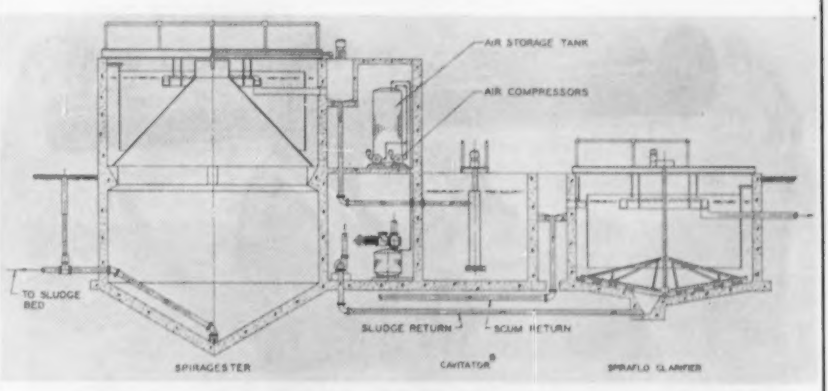


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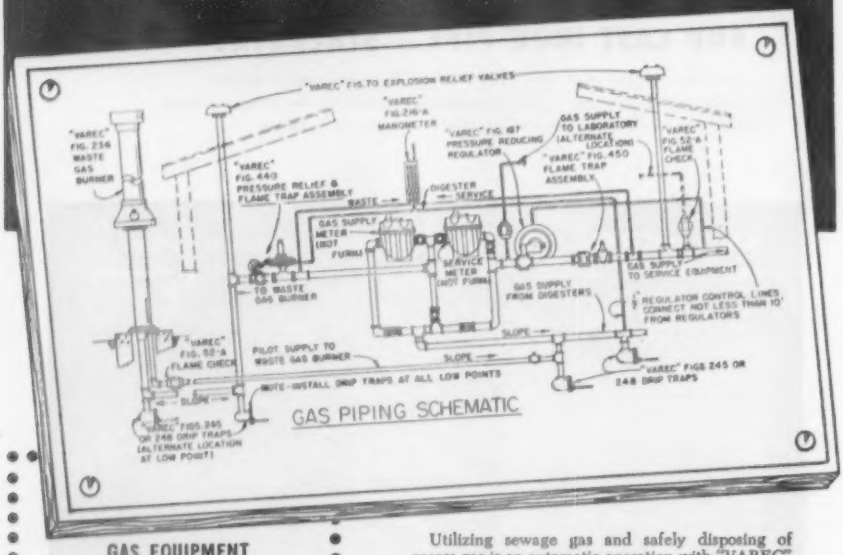
"VAREC" FIG. TO EXPLOSION RELIEF VALVES
"VAREC" FIG. 236 WASTE GAS BURNER
"VAREC" FIG. 440 PRESSURE RELIEF & FLAME TRAP ASSEMBLY
"VAREC" FIG. 216-A MANOMETER
"VAREC" FIG. 107 PRESSURE REDUCING REGULATOR
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"VAREC" FIG. 52-A FLAME CHECK
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REGULATOR CONTROL LINES CONNECT NOT LESS THAN 10' FROM REGULATORS
"VAREC" FIG. 52-A FLAME CHECK
PILOT SUPPLY TO WASTE GAS BURNER
SLOPE
"VAREC" FIGS 245 OR 248 DRIP TRAPS
NOTE - INSTALL DRIP TRAPS AT ALL LOW POINTS
"VAREC" FIGS. 245 OR 248 DRIP TRAPS (ALTERNATE LOCATION AT LOW POINT)
GAS PIPING SCHEMATIC

## GAS EQUIPMENT SPECIFICATIONS

**PRESSURE RELIEF AND FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 440

**FLAME TRAP ASSEMBLY**
"VAREC" Fig. No. 450

**FLAME CHECK**
"VAREC" Fig. No. 52A

**EXPLOSION RELIEF VALVES**
"VAREC" Fig. No. 70-1

**WASTE GAS BURNER**
"VAREC" Fig. No. 236

**DRIP TRAPS**
"VAREC" Fig. No. 245 (automatic)
"VAREC" Fig. No. 248 (hand operated)

**MANOMETERS**
"VAREC" Fig. No. 216A

"Varec"

Utilizing sewage gas and safely disposing of excess gas is an automatic operation with "VAREC" Equipment incorporated into your sewage plant design. With this equipment, accurate gas pressures are maintained in all service lines. As soon as the digesters make more gas than required for service, the pressure relief valve to the waste gas burner opens to permit safe burning of the excess.

Flame flashback to valuable equipment is prevented with "VAREC" Flame Traps and Flame Checks. The flame arresting element of the Flame Trap is designed to eliminate flame propagation of even more inflammable gases than encountered in sewage service. This element is the same as that used in "VAREC" Flame Arresters listed by the UNDERWRITERS' LABORATORIES for petroleum product storage.

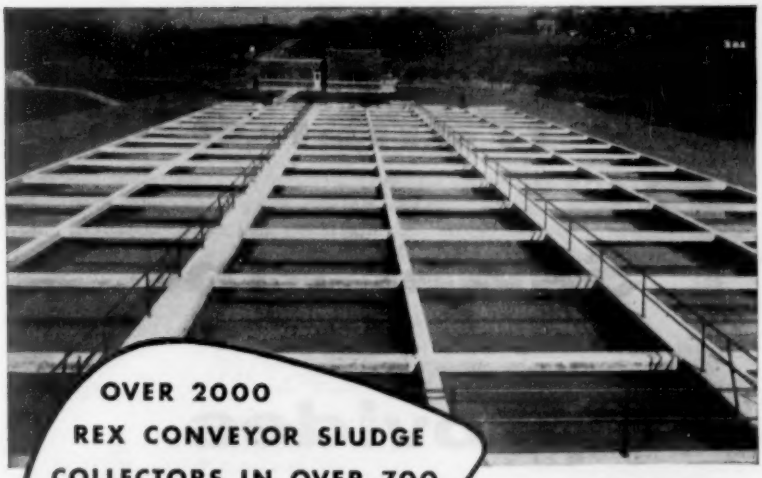
Emergency explosion relief is accomplished with "VAREC" Explosion Relief Valves. These valves should be installed outside of any buildings.

An enlarged engineering drawing of the above gas piping detail will be sent upon request. If you design sewage treatment plants, write today.

**THE VAPOR RECOVERY SYSTEMS CO.**
**COMPTON, CALIFORNIA, U. S. A.**
*Cable Address: VAREC COMPTON USA (All Codes)*

New York, N.Y. • Boston, Mass. • Pittsburgh, Pa. • Chicago, Ill. • Detroit, Mich. • St. Louis, Mo. • Houston, Texas • Tulsa, Okla. • San Francisco, Calif. • Seattle, Wash. • Minneapolis, Minn. • Honolulu, Hawaii

***Available from authorized Sewage Equipment agents throughout United States and Canada***



OVER 2000 REX CONVEYOR SLUDGE COLLECTORS IN OVER 700 CITIES AND INDUSTRIES!

WHAT BETTER PROOF of Rex superiority?

**YES** over 700 cities and industries rely on Rex® Conveyor Sludge Collectors for efficient, dependable and economical operation. They are applicable for all types of sludge handling or surface skimming conditions in either sewage, water or industrial waste treatment application.

Here are some of the time-proven features of Rex Sludge Collectors:

★ ***Balanced Equipment Design***—design proportionate throughout.

★ ***Rex Z-Metal Chain and attachments***—resist corrosion and wear.

★ ***Self-Aligning Bearings***—compensate for tank irregularities.

★ ***Centralized, Hardened Wearing Shoes***—eliminate splitting strains on wooden scraper flights.

★ ***Offset Split Drive Sprockets***—eliminate cantilevered brackets.

★ ***Double Life Sprockets***—chain engages every other sprocket tooth.

★ ***Drive Unit***—compact, totally enclosed. Shear pin protection.

★ ***Sub-Assemblies***—shop assembly of drive units and shaft assemblies assure proper alignment and fit.

**MAKE SURE YOU WILL BE THE NEXT ONE** to profit from Rex design and Rex quality. Get all the facts on Rex Conveyor Sludge Collectors. Call your nearest Rex Sanitation Engineer or write for Bulletin 47-9. Chain Belt Company, 4606 W. Greenfield Ave., Milwaukee 1, Wisconsin.

CHAIN BELT REX COMPANY

**Chain Belt** COMPANY OF MILWAUKEE

Atlanta • Baltimore • Birmingham • Boston • Buffalo • Chicago • Cincinnati • Cleveland
Dallas • Denver • Detroit • El Paso • Houston • Indianapolis • Jacksonville • Kansas City
Los Angeles • Louisville • Midland, Texas • Milwaukee • Minneapolis • New York
Philadelphia • Pittsburgh • Portland, Ore. • West Springfield, Mass. • St. Louis
Salt Lake City • San Francisco • Seattle • Tulsa • Worcester
*Distributors in Principal Cities in the United States and abroad*
*Export offices:* 4800 W. Mitchell Street, Milwaukee, Wisconsin; and 19 Rector St., New York City

# Transite Sewer Pipe provides these 4 basic economies

The engineer, the contractor and the taxpayer—all benefit when Transite® Pipe is used for sewer lines. Costs are cut in many ways—among them the four basic Sewer Pipe economies . . . in system design . . . in installation . . . in operation . . . in maintenance. If you make a quick run-through of the following condensed check list, chances are you will find savings which apply directly to your sewer system problems.

For further information and your copy of TR-94A, helpful widely used Sewer Design Flow Chart based on the Manning Formula, write Johns-Manville, Box 60, New York 16, New York.

**Johns-Manville**

# 1. System Design

**(Typical Economies)**

- Use of smaller diameter pipe
- Installation at flatter slopes
- Installation in shallower trenches
- Savings in amount of material excavated
- Smaller earth loads
- Elimination of cradling
- Location of treatment plant at higher level
- Elimination of pumping

**Users have found**—With its high flow capacity (flow coefficient n=0.010 derived from the Manning formula) and with its maintained strength, Transite Sewer Pipe contributes to typical system design economies.

# 2. Installation

**(Typical Economies)**

- Fewer joints
- Easier Handling
- Smaller crews
- Speedier assembly
- Assurance that joints pass severe infiltration tests

**Users have found**—With its longer lengths, light weight, ease of assembly and tight, quickly made joints, Transite Sewer Pipe contributes to typical installation economies.

# 3. Operation

**(Typical Economies)**

- Infiltration treatment cost drastically reduced
- Only normal sewage treated

**Users have found**—With its tight joints connected by Johns-Manville's Ring-Tite® Coupling, Transite Sewer Pipe contributes to typical operation economies.

# 4. Maintenance

**(Typical Economies)**

- Tree roots kept out—minimizes cleaning
- Need for frequent inspections reduced
- Sewers kept smooth and intact—pipe stays strong, joints stay resilient

**Users have found**—With its maintained strength and with its tight joints, Transite Sewer Pipe contributes to typical maintenance economies year after year.

## TRANSITE SEWER PIPE

**the asbestos-cement sewer pipe with the tight joints**

JOHNS-MANVILLE JM PRODUCTS

THEY DON'T BURN MONEY IN SCHENECTADY

Designed by Havens & Emerson, New York, N. Y.
Constructed by McElwee-Courbis, Camden, N. J.

Instead, the new sewage disposal plant at Schenectady, New York, *saves* money—sizable sums accruing from the sale of Orgro—Schenectady's effective soil conditioner and fertilizer composed entirely of flash-dried sewage sludge.

As in many other communities, a C-E Flash Drying System has converted what would otherwise be a bothersome liability into a revenue-producing asset. By drying, packaging and selling its sludge, and then deducting all fuel, power, labor and bagging costs from the revenue received, Schenectady nets approximately $15.00 for each ton of dry solids sold. Thus far the demand for Orgro has been so great that an average week's production is sold at the plant in a matter of hours. During the winter months, when consumer demand may drop off, Orgro will be bagged, stored and kept ready for use the following spring on the city's parks and golf courses.

Had Schenectady elected to incinerate its sludge, not alone would all revenue be eliminated, but in addition, a cost of about $3.00 per ton would be incurred for ash disposal—a substantial item, since roughly 50% of the original dry weight of incinerated sludge remains as ash.

In communities where the character of the sludge makes it unsuitable for use as fertilizer, incineration may be the only answer. But in the many instances where these limitations do not apply, burning sludge may be equivalent to burning money.

Whether you plan to incinerate or dry, the C-E Raymond Flash Drying System allows you to do either at will. Like the communities listed at the left, you, too, can end your sludge disposal problems effectively and at less cost with the service-proved C-E Raymond System. For full information, contact the C-E Raymond office nearest you. A C-E specialist will be glad to help you. 8-792A

**C-E RAYMOND FLASH DRYING SYSTEMS PRODUCING FERTILIZER**

| CITY | TREATMENT | NO. UNITS | SIZE OF UNITS Lb. Water per Hour per Unit | INSTALLED CAPACITY Tons Fertilizer Per Year |
|---|---|---|---|---|
| Baltimore, Maryland | Act. Dig. | 3 | 6,140 | 29,860 |
| Battle Creek, Michigan | Pri. Dig. | 1 | 2,370 | 2,550 |
| Chicago, Illinois | | | | |
| Calumet | Activated | 3 | 6,667 | 15,850 |
| Southwest | Activated | 8 | 21,000 | 148,500 |
| Southwest Ext. | Activated | 6 | 21,000 | 40,500 |
| Edgewater, New Jersey | Pri. Dig. | 1 | 795 | 150 |
| Fond Du Lac, Wisconsin | Pri. Dig. | 1 | 2,350 | 1,300 |
| Houston, Texas | Activated | 2 | 12,000 | 30,400 |
| Lansing, Michigan | Act. Dig. & Garbage | 1 | 6,667 | 6,780 |
| Los Angeles, California | Act. Dig. | 4 | 22,500 | 79,500 |
| Recife, Brazil | Pri. Dig. | 1 | 943 | 1,280 |
| San Diego, California | | | | |
| #1 Plant | Pri. Dig. | 1 | 3,500 | 7,500 |
| #2 Plant | Pri. Dig. | 1 | 9,000 | 13,200 |
| San Francisco, California | Pri. Dig. | 3 | 6,250 | 35,400 |
| Schenectady, N. Y. | Pri. Dig. | 1 | 3,370 | 2,970 |
| Sheboygan, Wisconsin | Pri. Dig. | 1 | 3,040 | 3,060 |
| Stamford, Connecticut | Pri. Dig. | 1 | 3,330 | 1,780 |
| Washington, D. C. | Pri. Dig. now Act. Dig. later | 3 | 12,000 | 85,500 |
| Wyomissing, Pennsylvania | Pri. Dig. | 1 | 2,218 | 848 |

**COMBUSTION ENGINEERING** C-E

RAYMOND DIVISION

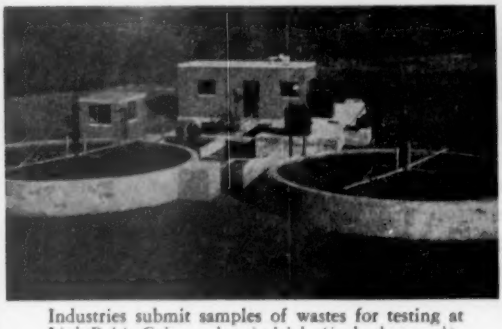
1315 North Branch Street, Chicago 22, Illinois

Eastern Office: 200 Madison Ave., New York 16, N. Y.

Western Office: 510 W. Sixth St., Los Angeles 14, Calif.

ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL

Sewage treatment plant (inset) serves Link-Belt Company Plant at Colmar, 25 miles outside Philadelphia. Except for chemical laboratory used by Sanitary Engineering Dept. for customer service, it's a typical Link-Belt system.



Industries submit samples of wastes for testing at Link-Belt's Colmar chemical lab (in background).

Straightline collectors are used in primary and final settling tanks. Here operator tilts scum pipe.

# Clean up industrial wastes

## with Link-Belt equipment engineered to your exact needs

TODAY waste treatment must be considered as part of the manufacturing process. In moving from metropolitan areas or locating at rural sites, many plants find it necessary to treat their own liquid industrial and sewage wastes. This is particularly true with increased anti-pollution legislation, both State and Federal.

Link-Belt is a highly qualified designer and manufacturer of waste treatment equipment. More, Link-Belt recommendations represent cumulative judgment acquired in many installations—not only in industrial wastes, but on large municipal water and sewage treatment plants as well. In many cases, Link-Belt's combination of design and quality equipment has enabled industries like steel, chemical processing, canning, packing, paper and many others to reclaim valuable by-products while reducing pollution.

Whether your plant is rural or urban . . . call your nearest Link-Belt office. Our specialists—cooperating with your own engineers, chemists and consultants—will work out the finest in modern water or waste treatment plants for you. Here you can also get expert advice on your complete conveying and power transmission needs.

**LINK-BELT**

**SANITARY ENGINEERING EQUIPMENT** 19,700

LINK-BELT COMPANY: Executive Offices, 307 N. Michigan Ave., Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World.

# INCINERATION

## for the small community

*It, too, can have the Best!*

Morse Boulger Incinerator serving Lucas & Hunt Village, St. Louis, Mo.

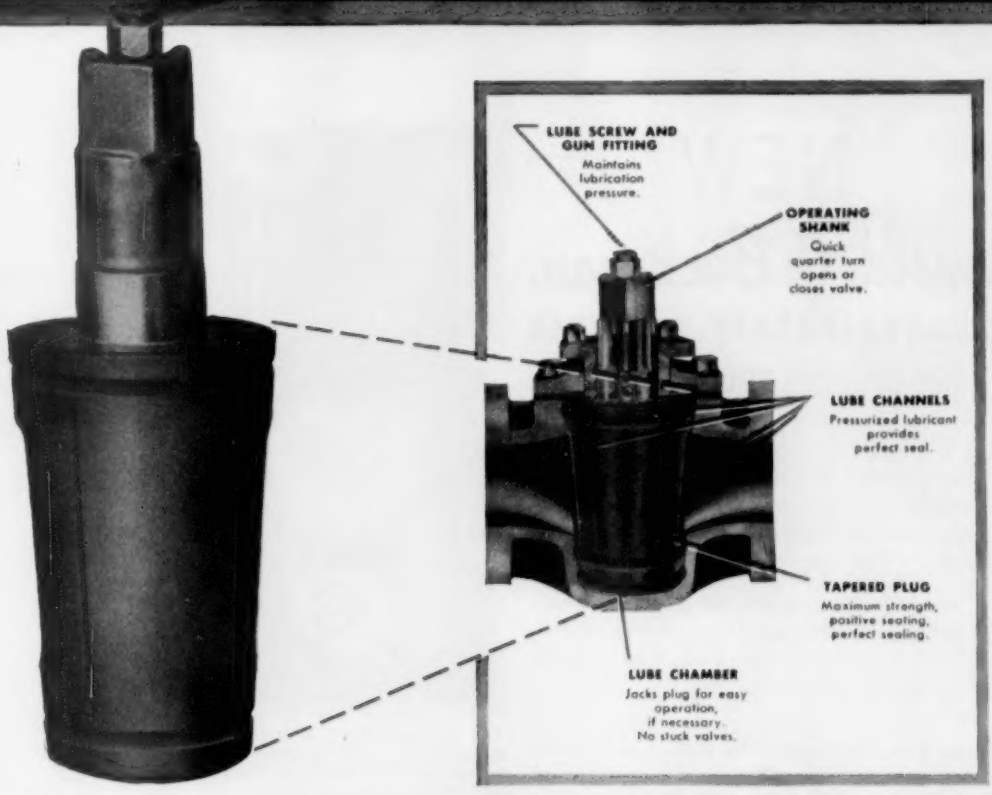
The old-fashioned refuse dump—no matter how distantly located from the town—is still an eyesore, a health menace and a nuisance. Haulage to it and bulldozing (which should be done anyway) cost money.

Morse Boulger, while serving very large cities with high tonnage incineration, has never neglected the small community. It, too, is entitled to the best in incineration . . . which Morse Boulger Engineers can provide.

Have your consulting engineer get in touch with us about your requirements. We have basic drawings all set up for several types of incinerators in a wide range of capacities. We can expedite the plan you need.

**MORSE BOULGER DESTRUCTOR CO.**

205-D EAST 42nd STREET • NEW YORK 17, N. Y.


LUBE SCREW AND GUN FITTING
Maintains lubrication pressure.
OPERATING SHANK
Quick quarter turn opens or closes valve.
LUBE CHANNELS
Pressurized lubricant provides perfect seal.
TAPERED PLUG
Maximum strength, positive seating, perfect sealing.
LUBE CHAMBER
Jacks plug for easy operation, if necessary. No stuck valves.

# Tapered Plug + Lubricant Sealing = Trouble-Free Economy

## when you use **Rockwell**-Nordstrom **Valves**

The tapered plug principle in Rockwell-Nordstrom valves has proven best for sewage and wastes services because it insures perfect seating and permits the plug to be hydraulically jacked for *instant* operation. The pressurized film of lubricant that forms the *leakproof seal* between plug and body is much more effective than the uncertain metal-to-metal seal on ordinary valves . . . more economical, too, because there's nothing to wear out. And lubrication also makes the *quarter-turn operation* smooth and easy.

Rockwell-Nordstrom, *the original lubricated plug valve,* is the result of forty years of manufacturing leadership and "know-how." A special booklet, "Rockwell Products For Sewage and Wastes Services" tells you how Rockwell-Nordstrom valves and Rockwell meters and regulators can help you do your job better and at lower cost per year. The booklet is yours for the asking . . . just send the coupon today.

**ROCKWELL**-Nordstrom **VALVES**

**LUBRICANT SEALED FOR POSITIVE SHUT-OFF**

Rockwell Manufacturing Company
Pittsburgh 8, Pennsylvania

DEPT. 7-D

☐ Please send me Bulletin C-5200.
☐ Please have your sales engineer call.

Name _____ Title _____

Address _____

City _____ Zone ___ State ___

# NEW

# Arnold O. Beckman

## DISSOLVED OXYGEN ANALYZER

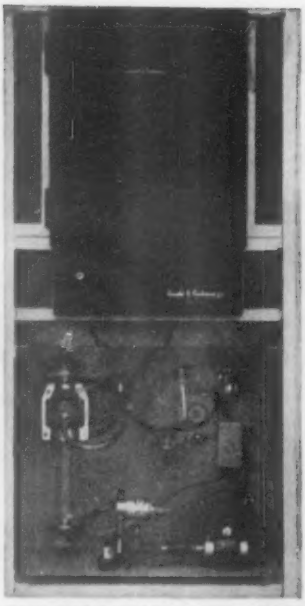
## for continuous measurement!

The accurate measurement of dissolved oxygen in fluid process streams is widely recognized as an important control factor in such municipal and industrial operations as sewage and water treatment . . . waste disposal . . . petro-chemical and chemical processes . . . food processes . . . and many others.

Now, you can make such measurements—continuously, simply and accurately—with the newly-developed Arnold O. Beckman Model 1A3B Dissolved Oxygen Analyzer!

- **The new Model 1A3B combines the field-proven Arnold O. Beckman paramagnetic principle of oxygen measurement with an improved method of stripping to provide a measurement specific for oxygen.**
- **The Model 1A3B is factory-calibrated to read in percent saturation so that efficiency of aeration or deaeration is shown directly. Or if preferred, the instrument can also be supplied to provide readings directly in parts-per-million.**
- **The Model 1A3B can be directly connected to any standard potentiometer-type recorder or indicator. No special accessory equipment is needed.**
- **Using the Model 1A3B is far superior—in speed, accuracy and convenience—to conventional chemical methods—and provides—immediately and continuously—the necessary control information for maintaining optimum processing uniformity.**

With a few variations the Model 1A3B can be adapted to a wide range of application requirements . . . to handling sludges and other liquids having high concentration of solids . . . to handling samples under abnormal pressures or temperatures . . . and to other difficult sampling conditions.



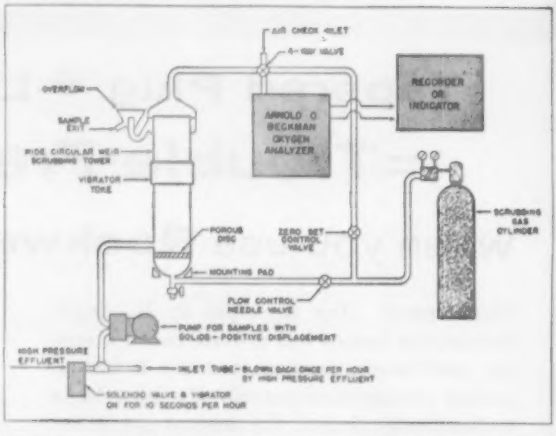
*The Model 1A3B is a complete, compact unit—with the Analyzer in top compartment and the scrubbing unit below.*

Continuous record

Handles fluids, slurries, sludges, etc.

Simple operation

Highly accurate


AIR CHECK INLET
OVERFLOW
SAMPLE EXIT
RECORDER OR INDICATOR
ARNOLD O. BECKMAN OXYGEN ANALYZER
VIBRATOR TONE
SCRUBBING GAS CYLINDER
POROUS DISC
ZERO SET CONTROL VALVE
MOUNTING PAD
FLOW CONTROL NEEDLE VALVE
PUMP FOR SAMPLES WITH SOLIDS—POSITIVE DISPLACEMENT
HIGH PRESSURE EFFLUENT
INLET TUBE—BLOWN BACK ONCE PER HOUR BY HIGH PRESSURE EFFLUENT
SOLENOID VALVE & VIBRATOR ON FOR 10 SECONDS PER HOUR

*The Principle is simple and positive. The constantly-fresh test sample in scrubbing tower is stripped of dissolved oxygen by inert scrubbing gas—and result measured by Analyzer. Measurement is continuous and accurate!*

**RANGES—from a maximum of 0-100% $O_2$ saturation to a minimum of 0-5 ppm, full scale. Intermediate ranges are also available.**

# Arnold O. Beckman INC.

**1020 MISSION STREET, SOUTH PASADENA 19, CALIFORNIA**

**Get the full story** *on this new Arnold O. Beckman development by writing directly for information on the Model 1A3B Dissolved Oxygen Analyzer. Ask for Data File #13-O-45.*

**HANDLING 11,000,000 GALLONS PER DAY,** the new sewage plant at Salem, Oregon, has Worthington pumps for continuous, economical pumping power. John W. Cunningham & Associates, Portland, Oregon, were the Consulting Engineers for this project.

# Salem's sewage system relies on these pumps

". . . since the day our plant opened in 1952, Worthington pumps have been in daily operation — with never a breakdown. And because these pumps are the very life-line of our plant, their reliability has proved invaluable."

That's what Chief Operator Cliff Reed says about the eight Worthington centrifugal pumps at work in the new sewage disposal plant serving Salem, Oregon.

Mr. Reed isn't alone in his opinion about the rugged Worthington units. We've had similar reports wherever Worthington pumps, comminutors or engines have been used — and that means water works and sewage plants all over the world.

Helping municipalities with their sewage and water works problems is our job today — has been for over 100 years. Write today for Bulletin W-317-B16 to Worthington Corporation, Public Works Division, Harrison, New Jersey. W.4.11

**WORTHINGTON**

***ALL MAJOR PUBLIC WORKS EQUIPMENT UNDER ONE RESPONSIBILITY***

**Water Works Pumps • Sewage Pumps • Comminutors • Vertical Turbine Pumps • Vacuum Pumps**

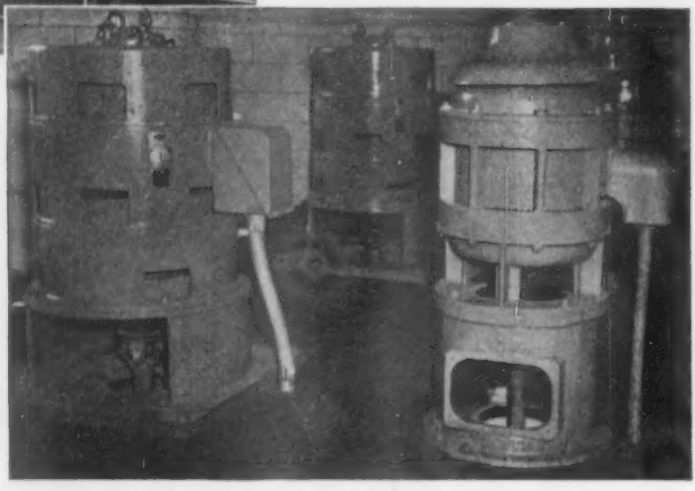
## Long-wearing

# INERTOL® PAINTS

## *specified* in Elmira, New York, plant

**Sparkling protection** was afforded this big gas engine at Elmira's Sewage Treatment Plant with Inertol Glamortex® Enamel. All surfaces were first primed with Inertol Quick-Drying Primer No. 626, a top-quality rust inhibitor which provides a perfect bond for the finish coats.

**Easy maintenance** of this battery of sludge pump motors was achieved with Glamortex Enamel, Battleship Grey No. 331. This easy-to-clean paint stands up for years under abrasion, oil spillage and frequent cleaning.



### Inertol Paints meet precise requirement of plant designed by Nussbaumer, Clarke & Velzy

For top protection, Elmira's Sewage Treatment Plant needed paints that would provide lasting durability, elasticity and chemical resistance. That's why Inertol coatings were chosen for this modern plant which was designed and constructed under the supervision of Nussbaumer, Clarke & Velzy. Inertol meets all these exacting requirements. For 18 years, the city of Elmira has been using hundreds of gallons of Inertol Paints—bituminous coatings as well as colored enamels.

All over America, thousands of Inertol-painted installations speak for this paint's economical and efficient superiority. Whatever your specific painting problem is, there's sure to be an Inertol coating to solve it. Ask to have your local Inertol Field Technician call. Or write for our free "Painting Guide." It's prepared especially for Consulting Engineers, Specification Writers, Design Engineers and Plant Superintendents. Send for this valuable booklet today.

## INERTOL CO., INC.

482 Frelinghuysen Ave.
Newark 5, N. J.

27H South Park
San Francisco 7, Calif.

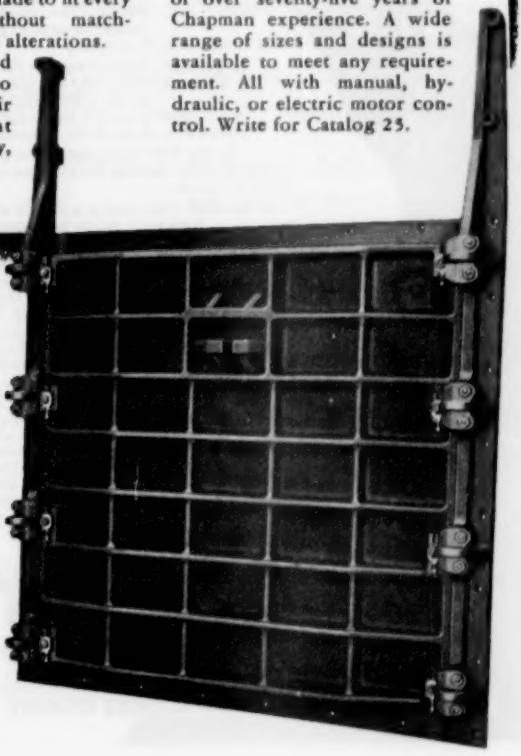
## *Here's Why Installation is Faster, More Economical with*

# CHAPMAN
## *Standard*
# SLUICE GATES

Installation is faster and simpler with a Chapman Standard Sluice Gate because component parts are absolutely interchangeable, made to fit every installation without match-marking or field alterations.

Standardized manufacture also means that repair or replacement parts, if necessary, fit perfectly into place without alterations.

Modern Chapman Standard Sluice Gates are the products of over seventy-five years of Chapman experience. A wide range of sizes and designs is available to meet any requirement. All with manual, hydraulic, or electric motor control. Write for Catalog 25.



**THE CHAPMAN VALVE MFG. COMPANY**

INDIAN ORCHARD, MASS.

# how much does it cost...

to have *Safest* CHLORINATION?

*Nothing*—when you buy a Fischer & Porter Chlorinator. That's true because fool-proof safety features are already engineered into this modern, instrument-type chlorinator.

The F&P Chlorinator is instrument engineered from top to bottom to be absolutely safe in any emergency—and the safety features respond instantly. The mechanical design—without hydraulic devices to introduce time lag—make this a certainty . . .

In the F&P Chlorinator you can take a hammer and shatter the flowmeter tube—and the chlorinator shuts down *instantly*.

In the F&P Chlorinator you can pull the flow setting needle valve right out of its socket—and the chlorinator shuts down *instantly*.

In the F&P Chlorinator you can shut off the ejector water supply while leaving the chlorine on—and the chlorinator shuts down *instantly*.

In the F&P Chlorinator a simple series of hand manipulations tests each safety component—or shows the reason for malfunctioning should it ever occur.

These safety advantages are yours in the Fischer & Porter Chlorinator. They cost you not one penny more at the outset, since the F&P Chlorinator is lower in first cost. They avoid constant costs of repeated safety tests and checks. They assure you against high costs of repairs and maintenance. We don't put our safety devices under a bell jar—they are right out in the open where you can see and touch them.

These engineered features—*instrument-type engineering*—make the F&P Chlorinator the safest ever built. And you get all these safety features *plus* ease of operation, dependability proven in over 600 operating units, complete corrosion resistance—everything you should have in a chlorinator—and you get them for even less cost in the initial purchase. Write today for full information, details on free trial offer, and *absolute guarantee of satisfaction.*

*complete process instrumentation*

FP FISCHER & PORTER CO.

1145 Fischer Road, Hatboro, Penna.

18 YEARS SUCCESSFULLY MANUFACTURING CHLORINE CONTROL EQUIPMENT

# R.. is for Reliability

Each one of a dozen cities has relied upon and been faithfully served for more than a dozen years by its Nichols Herreshoff incinerator . . . without a single emergency arising in sludge disposal.

Nichols Herreshoffs have and will run for months and years without a shut-down for repairs. Many of these units in operation today have not been shut down for repairs in over a year.

No other method of sludge incineration can better the Nichols record nor, to date, has any other method equaled its record . . . that's Reliability.

## Nichols Herreshoff

**Multiple Hearth Dryer Incinerators**

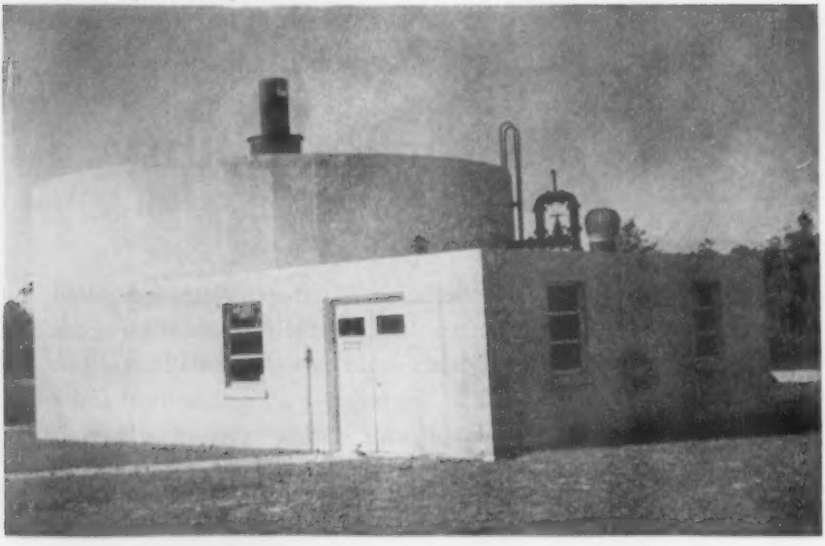
## Nichols Engineering & Research Corp.

**70 Pine St., New York 5, N. Y.**

**1637 N. Illinois St., Indianapolis 2, Ind.**

**1477 Sherbrooke St. W., Montreal 25, Canada**

*Florida's big clean-up moves ahead!*



Progressive Eustis, Florida adopts

**PFT "CONTROLLED DIGESTION"**

Joining Tallahassee, Tampa, Orlando, and other Florida cities, Eustis is taking part in a great *state-wide* sewage treatment program! Eustis, like the larger plants mentioned (and others under construction), chose modern PFT equipment for effective treatment through "controlled digestion."

Designed for complete treatment of a 5,500 population equivalent, the plant commenced operation in June, 1953. Treating a sewage flow of 100 gallons per capita per day, it uses high rate filters with chlorination and discharges into Trout Lake, a tributary to Lake Eustis.

Essential to the plant's effective treatment is the *PFT Floating Cover* for the 30 ft. digester (13,280 cu. ft. capacity). Floating Covers accelerate digestion by providing positive scum submergence. They simplify operations by eliminating the need for fixed levels—additions and withdrawals can be made at times suited to the overall operation.

In addition, Floating Covers reduce explosion hazards because gas collected under the cover, is maintained at positive pressure under all operating conditions. Costly breakdowns are reduced because all moving parts are eliminated from inside the digester. Since heat is supplied from *external* heaters, all cleaning and maintenance take place *outside* the tank.

Other PFT equipment installed at Eustis includes: *Heater & Heat Exchanger Unit* (100,000 B.T.U. per hour); *Flame Traps; Pressure Relief Waste Gas Flame Trap; Waste Gas Burner; Auxiliary Flame Cell; Gas Pressure Gauge; Drip Taps.*

The Eustis plant has demonstrated that PFT equipment can serve the smaller as well as the largest cities. In all installations, PFT assists consulting engineers by showing the adaptability of its equipment in meeting specific plant requirements.

*Design of plant by* / *Briley, Wild & Associates, Consulting Engineers; Daytona Beach, Fla.*

P.F.T.

waste treatment equipment exclusively since 1893

**PACIFIC FLUSH TANK CO.**

4241 Ravenswood Avenue
Chicago 13, Illinois

PORT CHESTER, N. Y. • SAN MATEO, CALIF. • CHARLOTTE, N. C. • JACKSONVILLE • DENVER

# SEWAGE AND INDUSTRIAL WASTES

***Journal of the Federation of Sewage and Industrial Wastes Associations***

**Volume 27** | **April, 1955** | **Number 4**

## Contents

**Sewage Works**

Electric Power Reliability in the Sewage Plant. By N. L. Hadley and E. O. Potthoff 393

Concentration of Activated Sludge by Centrifuge. By Leland Bradney and R. E. Bragstad ..... 404

Discussion by L. S. Kraus ..... 410

Discussion by D. M. Landis ..... 411

Effect of Recirculation on Trickling Filter Performance. By J. H. Sorrels and P. J. A. Zeller ..... 415

Two-Stage Operation of Activated Sludge Plants. By Karl Imhoff ..... 431

Transformation and Effects of Reduced Sulfur Compounds in Activated Sludge Treatment. By Donald B. Aulenbach and H. Heukelekian ..... 434

Flow Measurement in Sewage Works. III. Secondary Instruments, Controls, Operation, Maintenance. By Walter H. Brown and George E. Symons ..... 449

**Industrial Wastes**

The Anaerobic Contact Process as Applied to Packinghouse Wastes. By George J. Schroepfer, W. J. Fullen, A. S. Johnson, N. R. Ziemke and J. J. Anderson ... 460

**Stream Pollution**

Legal Implications of Stream Pollution. By George E. Owen ..... 487

**The Operator's Corner**

Service—Criterion for Operator Certification. By H. S. Smith ..... 494

1954 Operators' Forum:
Salaries and Job Classifications ..... 495

Plant Beautification. By George T. Lohmeyer ..... 502

Interesting Extracts from Operation Reports: DeKalb, Ill. ..... 504

Operation and Maintenance of Sewage Pumps. By George Strudgeon ..... 506

Tips and Quips ..... 511

**Editorials**

Pollution Control Means Better Health ..... 513

Federation Office Moved to Washington, D. C. ..... 513

**Book Reviews** ..... 514

**Proceedings of Member Associations**

Florida Sewage and Industrial Wastes Association ..... 156a

Rocky Mountain Sewage Works Association ..... 158a

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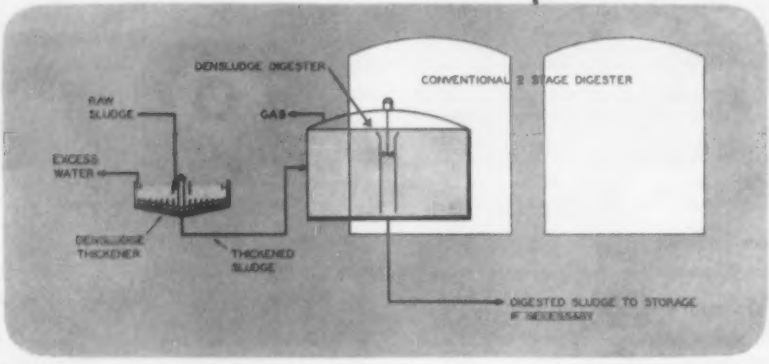


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# Sewage Works

## ELECTRIC POWER RELIABILITY IN THE SEWAGE PLANT *

By N. L. Hadley and E. O. Potthoff

*Respectively, Industrial Power Application Engineer and Water and Sewage Application Engineer, General Electric Co., Schenectady, N. Y.*

The number of potential mechanical and electrical failures that are possible in the sewage plant is large enough to tax the imagination. Failures are bound to occur. It is the job of plant engineers, plant superintendents, and consulting engineers to anticipate the causes of at least major failures and to build some relief measures into the system and into the operating procedures.

The desire to reduce the number of plant failures to a minimum has lead engineers to study methods of improving the reliability of the system and its components. Reliability may be defined as the ability of a system, process or machine to operate in a satisfactory manner.

The importance of reliability in the plant is shown clearly by these penalties of a power failure: the expense of cleaning up and the deterioration of relations with the public. Equipment in the plant can become completely jammed by debris or mired in by sediment. Processes can be upset for a considerable period. Restarting after the clearing of a failure may require a major effort. Considerable time and effort may be required to reestablish plant efficiency. The inability of the plant to pump sewage or the discharge of low quality effluent from the plant may seriously affect relations with residents of the sewer district, with groups such as sportsmans' organizations, and with state regulatory organizations.

### Purpose and Scope

This paper is addressed to several groups who contribute in different ways to sound planning and final successful performance of the plant. It is desirable for all of these contributing parties to understand the planned objectives, and to sense the importance of a well-coordinated relationship between the various parts of the over-all system. These groups are the power companies, consulting engineers, equipment suppliers, and those individuals in the sewer department officially responsible for planning and operating the plant.

The subject is approached from a broad, fundamental standpoint rather than the detailed technical viewpoint of the electrical engineer. The subject is handled in three parts: the allowable power outage times, purchased-power reliability, and reliability of the sewage plant electric power-distribution system.

The failure of a single motor or its supply cable may not be serious. This generally is remedied by starting a spare motor. A much more serious possibility is a power interruption affecting all motors operating the same type of plant equipment, such as all raw sewage lift pumps or all bar

* Presented at 27th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Cincinnati, Ohio; October 11–14, 1954.

screen drives. This paper deals with this latter more serious situation.

An electric utility is considered to be the only power source, since the majority of plants purchase their power from electric utilities.

It must be pointed out that although the subject of reliability can be and is approached statistically and by a study of incidence and probability of failure, there is no such thing as an empirical or mathematical solution to the whole problem. Therefore, the statistics included in this paper are to be used only as a starting point for sound electrical planning, with allowances made for the individual characteristics of the system concerned.

## Approach to Problem

A logical approach to the solution of the problem is as follows:

1. Determine as nearly as possible the allowable power outage time for each operation or process in the plant.
2. Investigate the probable maximum outage time in the electric utility service to the plant. The maximum expected interruption should be less than any of the allowable outage times. If not, a better grade of service reliability should be obtained.
3. Design the plant power system to provide a reliability adequate for the demands of each process or operation in the plant.

## Allowable Power Outage Time

The reliability demands on the electrical system and its components vary considerably from plant to plant and from operation to operation within a plant. Therefore, it is difficult to generalize and make blanket recommendations. It is felt, however, that general allowable outage times for various operations should be compiled so that the problem can be narrowed down to provide a starting point for its solution. Extreme care must be exercised in using these general data because of possible deviations in special situations.

Table I gives the results of a survey made to determine the approximate allowable outage times for various operations within the sewage treatment plant. These data reflect the thinking and experience of consulting engineers, plant managers, and equipment suppliers, and show a satisfactory degree of agreement among the individuals polled. On a few points, the most notable example being the allowable outage time for the grit removal chamber, considerable variation is possible because of the wide variation of grit flow to the plant. Time for the bar screens and the settling tank equipments may also vary. Those polled recognized this variation, but the ranges of their opinion fitted reasonably closely.

In several plant operations, it is possible to establish the allowable outage times by the use of several different criteria. For instance, the allowable outage time for the blowers of an activated sludge plant may be judged by effects on the quality of effluent, the difficulty of restoring the efficiency of the process, or the plugging of the diffusers. Judgment must be relied on in selecting the governing criterion.

Mechanically cleaned bar screens vary widely in allowable outage time because of wide variations in volumes of trash passed and differences in bar openings. In general, however, it seems reasonable that the racks may become plugged after approximately an hour of outage under the worst conditions. If no by-pass facilities are provided, this point may become critical. Therefore, under these conditions, the reliability of the power system feeding the bar screen drives may be considered as critical as the power supply to the raw sewage pump drives. A high degree of reliability is not necessary if station by-pass facilities are provided and free use of them is

**TABLE I.—Approximate Allowable Power Outage Times**

| Operation | Type | Criterion | Approx. Allowable Outage Time[1] (hr.) | Special Remarks |
|---|---|---|---|---|
| Screening | Mech. cleaned | Becomes essentially plugged | ¼–16 | No means provided for manual raking or operation |
| | Comminutor | Becomes essentially plugged | N.C. | Can be cleaned manually |
| Grinder | — | — | N.C. | Screenings could be otherwise disposed of for a medium term |
| Grit removal | Rect. or circ. | Collector mech. jams or grit passes into settl. tanks | ¼–72 | |
| Raw sewage pumps | — | — | — | Local conditions govern |
| Prim. sedimentation: | | | | |
| Collectors | Rect. or circ. | Mech. jams, low effl. quality | ¼–16 | |
| Sludge pump | Rectangular | Low effl. quality | ¼–16 | |
| | Circular | — | N.C. | If portable sludge pump is available |
| Aeration blowers | — | Clogging of diffuser media | 0 | |
| | | Maint. of good effluent | 1 | |
| Sec. sedimentation: | — | Maint. of satisfactory effl. | 1–12 | |
| Scrapers | — | Collector mech. jams | 24+ | |
| Sludge pump | — | — | N.C. | If portable sludge pump is available |
| Digesters: | | | | |
| Gas boiler | — | Adequate sludge storage or easy restart of dig. after power restoration | 7+[3] | Earth covered digesters |
| Sludge trans. pumps | | Adequate sludge storage | 7+[3] | |
| Sludge conditioning: | | | | |
| Sludge trans. pumps | — | None | N.C. | |
| Vacuum filters | — | None | N.C. | |
| Sludge conveyors | — | None | N.C. | |
| Chemical mixers | — | None | N.C. | |
| Elutriation pumps | — | None | N.C. | |
| Sludge drying system | — | None | N.C. | |
| Sludge incineration | — | None | N.C. | |
| Chlorination: | | | | |
| Pre-chlorination | — | Odors from plant | N.C. | Dry chem. could be added manually; gas could be drawn from cylinders without use of heaters |
| Post-chlorination | — | High coli count in effl. | N.C. | |
| Gas utilization: | | | | |
| Gas booster | — | Reliability demand of most critical load | Var. | |
| Lighting: | | | | |
| Building interior | — | — | N.C. | No national code applies; emergency lighting desirable |
| Outdoor | — | — | N.C. | |

[1] N.C. = not critical; Var. = variable.
[2] To successfully restart the process after a prolonged outage requires at least 4 days.
[3] Days.

permitted upon failure of voltage to the bar screen drives only.

The rate of deposit in the grit chambers certainly will vary depending upon the amount of rainfall and the amount of infiltration of sand into the sewers. If a power failure occurs coincidental with a heavy deposit of grit, undesirable conditions could be encountered within about 4 hr. Grit removal mechanisms could become mired in the grit, or grit could pass over into the settling tanks, allowing the grit to build up in the digesters or cause excessive wear of filter cloths. This difficulty can be prevented if by-pass facilities are provided and free use is permitted.

The allowable power outage time for the raw sewage pumps depends on the location of the plant. If the plant has no by-pass facilities, or if there is a limitation on their use, the allowable power outage time should be considered as practically zero. If by-pass facilities are provided and can be used freely, the allowable outage time may become very long. It is impossible to give specific data because of the extreme variety of requirements possible. Local conditions should be studied and each case must be judged on its merits.

The primary settling process is considerably less critical than the operations already mentioned. It is ex-

pected that the scraper mechanisms will mire in the sludge in from one to several days. This problem can be avoided completely if by-pass facilities are provided and their complete use is permitted.

The pumps used to pump sludge from the settling tanks have the same outage time as the scrapers, unless a portable sludge pump is available in the plant.

The activated sludge process presents a special problem in selecting allowable power outage times for the blower motors. Several different criteria should be recognized, the most important being the tendency for some or all diffuser media to clog if air pressure is lost. Service records in several plants indicate that clogging is a cumulative process and serious clogging need not be anticipated until several pressure failures have occurred. The number of outages appears to be more critical than the elapsed time of outages. If the diffuser media have shown a tendency toward clogging in service as a result of air pressure failure, the allowable outage time should be considered as zero (1).

The next criterion of importance is the deterioration of quality of effluent as the result of failure of the aeration system. The best opinion indicates that a failure of perhaps 1-hr. duration is allowable for the standard aeration process and several hours for the modified aeration process. This criterion might become predominant in situations where a high quality of effluent is demanded at all times.

The last criterion for the activated sludge process is the ability of the process to be re-established easily after an air pressure failure. Keefer (2) has shown by test that the activated sludge process can be re-established slowly following outages lasting as long as four days. Therefore, this criterion does not seem important in laying out the power system in the sewage plant.

The aeration process is one which can not be by-passed to avoid difficulties.

The failure of power to the secondary settling operation results in the deterioration of quality of effluent and the miring of the scraper mechanisms. Best estimates indicate that a variable period of 1 to 12 hr. may elapse before the quality of the effluent will degenerate seriously. A more important criterion is the miring of the mechanism in one or more days. The permanent sludge pump will have the same allowable power outage time, unless a portable sludge pump is used.

Usually, the digester building gas boiler and sludge transfer pump allowable power outage times are non-critical. This period may be judged by the amount of free available sludge storage capacity. Unless loaded heavily, an outage of roughly a week may be tolerated. These drives may, therefore, be considered as non-critical from a power outage standpoint.

The sludge conditioning process is not critical as to power outage, because no particular penalties result from a power failure. This conclusion applies to the sludge drying and sludge incineration process as well. Both pre- and post-chlorination appear non-critical because operators can feed dry chemicals manually into the flow.

One valuable operating procedure to follow is to operate intermittent-process machinery frequently to prevent excessive accumulation of materials. For instance, the mechanically cleaned bar screen should not become well covered before cleaning is started. A power failure at a time when the screen is almost covered allows but little time for corrective measures.

### Purchased-Power Reliability

The electric utilities have been remarkably successful in providing service reliability that meets the reasonable needs of their customers,

even though all of them are subject to some amount of service interruption.

A utility system consists of generators with their prime movers and station auxiliaries, transformers, circuit breakers and other switching and protective equipment, overhead lines, and underground cables. These components are integrated into a system specifically designed for economically serving all of the load in a particular large area. It is a design objective, where practical, to prevent a power outage for any consumer under a single failure or loss of a single part of the generating and transmission system, to which consumers are not ordinarily directly connected.

This high reliability in the backbone of the system is accomplished by (a) subdividing generating capacity into a number of units, usually in more than one station; (b) using parallel or loop arrangements in the system connecting circuits; and (c) often using interconnection ties with adjoining utility systems. It is also necessary to maintain certain amounts of reserve capacity at various points in the system to be able to accept the loss of any component.

The generation and transmission part of the system serves numerous substations, which in turn supply the distribution circuits and finally the service connections to each consumer. The service reliability for an individual customer will be affected by some single failures in the distribution circuits and also by all troubles in the typical single-circuit service to the user. The customary service for a given load at a particular location may not be reliable enough for a sewage plant. This question of adequate reliability, along with many other details of the purchased-power service, should be carefully reviewed with the power company as early as possible.

**TABLE II.—Reliability Standards for Residential, Small Commercial, and Small Industrial Customers Served from the Distribution System of One Electric Utility**

| Service Class | Interruptions per Customer per Year[1] | |
|---|---|---|
| | Number | Minutes |
| Urban | 1.5 | 60 |
| Rural | 3.0 | 120 |

[1] Outages of 2 min. or less not included.

**TABLE III.—Reliability Standards for Large Commercial and Industrial Customers Served from a High-Tension Line at 12 Kv. or Higher**

| Service Class | Max. Customer Demand (kw.) | Interruptions per Customer per Year[1] | |
|---|---|---|---|
| | | Number | Minutes |
| I | >7,500 | 1.5 | 30 |
| II | 1,001 to 7,500 | 3.0 | 60 |
| III | 0 to 1,000 | 6.0 | 120 |

[1] Outages of 2 min. or less not included.

The best progress can be made in such a discussion if the sewage plant representatives are prepared to state their problem in terms of estimated permissible outage times for the more critical loads, accompanied by an appraisal of the mounting damages that may result from progressively longer outages. A comparison between such data and the expected reliability of the proposed service will indicate whether improved service reliability will be necessary to meet reasonable objectives in the sewage plant performance.

Most power companies can provide information on probable service interruptions out of their operating records. One large electric utility has established reliability standards (3) as shown in Tables II and III. These standards were based on a 4-year record of operations and on the probability that the limits would be exceeded only once in seven outages.

The usual reference terms for outages are interruptions per year and total outage time per year, although a more useful kind of term for many

power users will be the maximum time for a single expected outage.

In those cases where a proposed service reliability does not appear to be adequate, a mutually satisfactory arrangement can usually be worked out with the power company. It may be possible for the power company to provide the improvement needed in a single-service connection by supplying from another point in the utility system, perhaps at a different voltage. Another solution more often found in larger plants is the use of more than one incoming line.

Two incoming lines in any of the arrangements termed duplicate service, loop service, or preferred-emergency service can give the very best in service reliability. However, the actual reliability of a particular service will depend on the extent to which the service arrangement insures that a single failure in the system, or in one of the incoming lines, will not cause a power outage for both lines.

## Reliability of the Sewage Plant Power-Distribution System

### *System Components and Functions*

The basic functions of the plant power-distribution system are (a) to subdivide and distribute the incoming power and (b) to transform to suitable utilization voltages as required for the plant electrical loads. The system is therefore the link between the purchased-power service conductors and the branch circuits supplying single motors, lighting loads, and occasionally heating loads.

The power-distribution equipment includes all of the incoming-line and plant-feeder switching equipment, transformers, and feeder cables. Physical equipment will sometimes include other components. An example is found in the low-voltage section of a unit substation where it may be advantageous to supply feeder circuits and motor-control and lighting circuits from the same bus in the same equipment.

### *Planning a Reliable System*

The preparation of plans and specifications for the power-distribution system and equipment is an engineering endeavor. It requires the services of a competent engineer with technical training, experience, a familiarity with equipment capabilities, and a knowledge of the provisions necessary for safe and convenient maintenance work later.

System planning must be undertaken at an early stage in the over-all planning to avoid compromises. The need for early planning requires early settlement of the process outage tolerances and of many details of the purchased-power supply.

There is no distribution system standardization. The system layout and the actual equipment specified may never be duplicated exactly because plants differ in the processes employed, in the plant physical arrangements, and often in the operating objectives. Although every system should be designed to satisfy particular requirements, this can still be done by using standard components within the practical limits of sound system engineering principles.

The system engineer works toward a balanced system design through a careful coordination of components. This effort is guided by an aim to achieve the most satisfactory combination of several important system characteristics, one of which is reliability.

Reliability, along with the various other system characteristics, is a quality that can be dealt with in the plans and specifications only by describing desired functions and a large number of physical and performance details of the equipment. All of the system characteristics are inter-related so that most of the equipment features covered will have some bearing on the

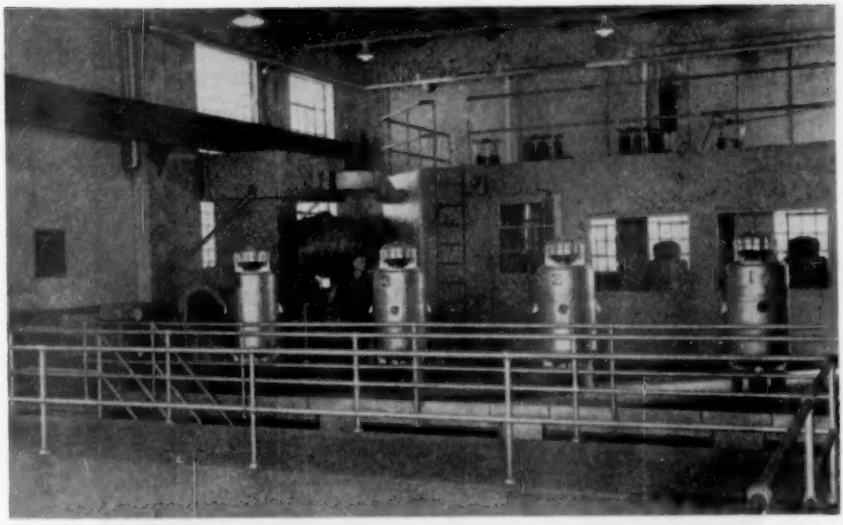

FIGURE 1.—Method of mounting control equipment in a room (right rear) supplied with clean air to minimize dust and corrosion difficulties.

reliability of the distribution equipment and system. Examples of a few points that will affect reliability in some measure are as follows:

1. The specification of equipment according to the applicable standards of ASA, AIEE, and NEMA is good insurance that details not mentioned in the bidding specifications will be taken care of in generally approved ways. Another advantage of using standard equipment items is that renewal parts and service in the event of trouble can be more readily obtained.

2. Hazardous or severely corrosive atmospheric conditions should be anticipated and guarded against. Figure 1 illustrates an increasingly popular and effective way of handling this problem by locating distribution and control equipment in a special room supplied with clean air.

3. Switching equipment should be selected to adequately handle system short-circuit currents (see Figure 2) as well as normal load currents.

4. System and component overcurrent protection limits the damage from abnormal overcurrents. A properly engineered protective system will have good selectivity between devices than can be actuated by the same overcurrent condition so that the smallest possible part of the whole system will be shut down.

5. Removable circuit breakers are a valuable aid in providing a safe, fast method of substituting a spare unit for one needing maintenance. Figure 3 shows a low-voltage draw-out circuit breaker removed from its normal operating position. A corresponding arrangement is standard for the circuit breakers used in metal-clad switchgear for higher system voltages from 2,400 to 13,800 v.

### *Judging Expected Reliability*

It is unfortunately very difficult to judge whether an electrical system built according to plans can be expected to provide a reliability adequate for plant process requirements. The nature of the problem is indicated in the following discussion.

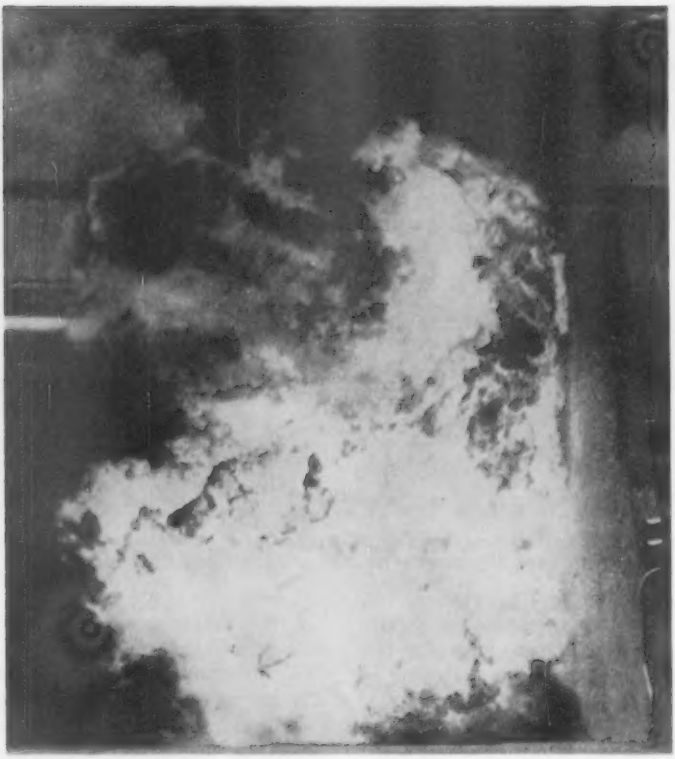

FIGURE 2.—Fire resulting from explosion of an oil-type circuit breaker subjected to a short-circuit duty above its rating.

A direct procedure that may seem practical is simply to compare the process outage tolerances with the outage times caused by plant distribution system failures. Perhaps some possibilities of failure could be dismissed on the basis that they constitute acceptable risks, but an intelligent decision requires reliable information on the probabilities of various failures. Actually the statistics are meager, and they are not in a form that allows comparisons with process outage times. For example, liquid-filled transformers have been credited with an expected failure rate of one per year for every 2,500 transformers. Modern metal-enclosed switchgear properly applied well deserves a high reliability rating, but no useable yardstick has been developed. A few studies have indicated that 13.8-kv. underground cables will have one failure per year for every 15 to 100 mi. of circuit. Data of this kind have some orienting value, but they are entirely unsuitable for gaging the performance that can be expected either of components or of a whole system at a particular installation.

A modified approach assumes that troubles of various kinds will be encountered in each of the system components. An estimate is then made of the time required to correct each assumed case of trouble. There will be few kinds of unexpected trouble that can be corrected in a time as short as 1 hr. The times will be affected by the abilities of the operat-

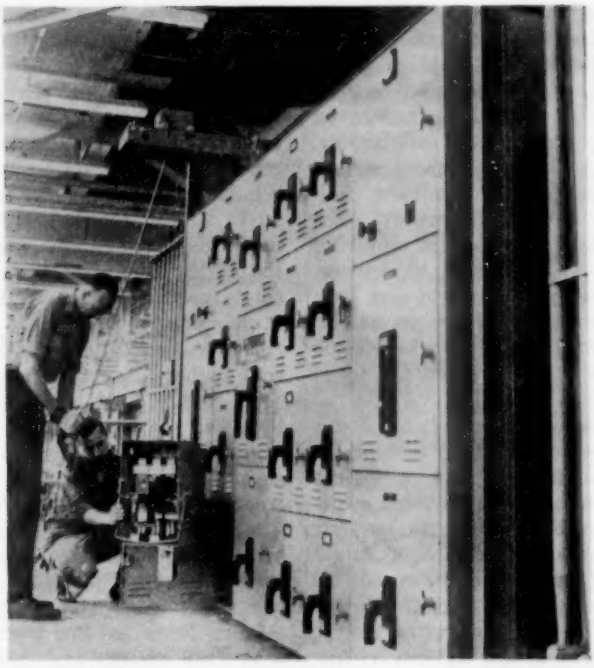

FIGURE 3.—Replacement of modern modular low-voltage circuit breaker unit in switchgear is comparatively simple and quick.

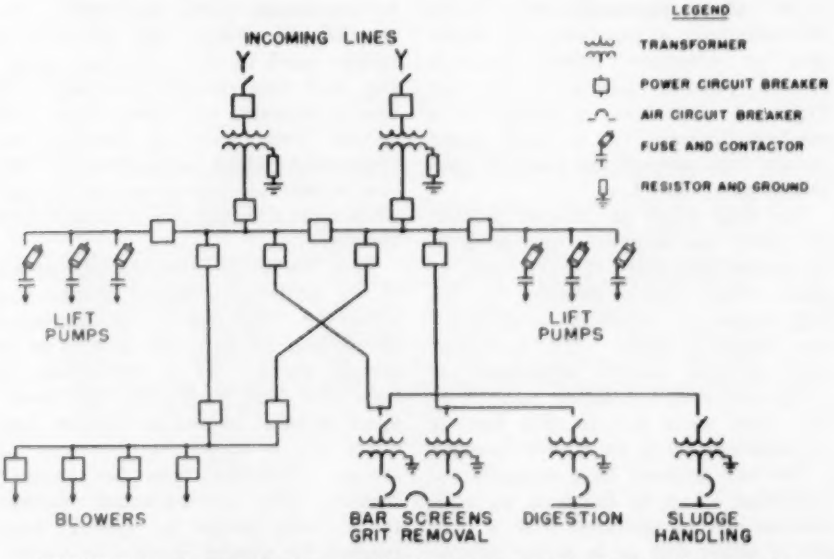


FIGURE 4.—Sewage plant power distribution system showing duplicate service reliability carried to critical-load buses.

ing personnel and by the amount of spare material and replacement parts that are kept available at the plant. Most of the occurrences would require longer times up to 8 hr. or more, even if temporary repairs were satisfactory. Then there would be the more serious types of possible, though rare, failures where a major important component is damaged to a point requiring days or weeks to rebuild or replace. A significant point brought out here is that even minor failures may cause interruptions likely to exceed some of the allowable process outage times in most plants.

Upon recognizing that failures can not be prevented and may not be ignored as calculated risks, a logical question is whether any system modifications can be adopted to prevent certain outages in the face of single failures. There are some practical circuit and equipment arrangements that are often employed after weighing the additional cost against an appraisal of the improved characteristics.

All of the variations of providing something further in system reliability under these circumstances, consist fundamentally of provisions for duplicate or alternate power channels around possible points of trouble. Figure 4 illustrates by means of a one-line diagram for a large plant system examples of the kind of provisions mentioned here.

The first point of interest is that the plant has duplicate service from the power company. In this type of plant a need can be assumed for the high degree of reliability implied by two incoming lines. To capitalize fully on this service advantage requires two main-substation transformers. The main bus in this case is sectionalized by a tie circuit breaker so the two sections have separate reliabilities. Any of the load on both sections can be operated with a failure of either line or in either substation transformer.

There will be a few cases where subdivision and duplication must be adopted for other reasons, such as the one of limiting the short-circuit duty on the main bus, resulting in a reduction in system cost. If the only reason for duplication is to improve reliability, the system may cost from 10 to 20 per cent additional without installing extra capacity for handling the entire load indefinitely through a single power channel. Where the reserve capacity is desired, the additional system cost may be up to 50 per cent higher.

In Figure 4 the most critical plant loads all have duplicate supply arrangements. The large lift pumps are supplied from the plant main bus. Another bus in the blower building has a parallel-circuit supply from the main bus, so the high service reliability is carried to that point for the benefit of the blower-motor loads. The smaller loads in the pump building area (bar screens and grit removal) receive similar treatment by employing a secondary-selective load-center unit substation. This unit takes care of important pump auxiliaries, the smaller lift pumps, and the various motors used in the screening, grinding, and grit removal processes. It also is indicated in Figure 4 that less critical loads, such as those in the digester building and those in the sludge handling processes, may be supplied from a simple radial distribution system.

This duplication through part or all of the power-distribution system has become a very popular arrangement throughout all industry, as well as in sewage plants. It is interesting to note that this preference has developed among operating people less often for a direct improvement in system reliability than for another reason. The arrangements permit ready, safe access to system components for needed changes or adjustments, and particularly for inspection

and maintenance, so that proper attention need not be deferred. This convenience will ordinarily work out to be an important benefit for improved system reliability, because a reasonable maintenance program is more likely to be followed.

*Steps Beyond Planning*

Although carefully engineered plans and specifications provide a necessary foundation for reliable system performance, a continuing effort is essential to a full realization of the intended reliability. The plans relating to reliability contemplate that good quality equipment will be purchased, that the material will be competently installed, and that an adequate maintenance program will be followed.

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## PROFESSIONAL OPPORTUNITY

Open nation-wide examinations for the position of Junior Sanitary Engineer have been announced by the New York State Department of Civil Service, for assignment in the State Department of Health.

Details as to salary, examination, qualifications and the method of applying may be obtained by inquiring about Examination No. 144, Junior Sanitary Engineer. Inquiries should be addressed to New York State Department of Civil Service, Examinations Division, 39 Columbia St., Albany 7, N. Y.

## NON-MEMBER MEETINGS OF INTEREST

The 10th Purdue Industrial Wastes Conference will be held May 9–11, 1955, at the Memorial Union, Purdue University. Details of the meeting program and accommodation arrangements may be obtained through Professor Don E. Bloodgood, Civil Engineering Hall, Purdue University, West Lafayette, Ind.

The 75th Annual Convention of the American Water Works Association will be held June 12–17, 1955, in Chicago, Ill. Details are available through AWWA headquarters, 521 Fifth Ave., New York 17, N. Y.

# CONCENTRATION OF ACTIVATED SLUDGE BY CENTRIFUGE *

By Leland Bradney and R. E. Bragstad

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The concentration and disposal of waste activated sludge is a problem of major importance in most activated sludge treatment plants due to its inherent characteristics, and in Sioux Falls this problem has assumed considerable proportions.

This city of over 55,000 population has had a consistant growth for more than 20 years. The volume of wastes treated at the present time is approximately 12 m.g.d., of which 3.5 to 4.0 m.g.d. is industrial, most of which is contributed by the local meat packing industry.

The initial treatment plant, installed in 1927, consisted of separate sludge digestion units and trickling filters. The demands of growth and more complete treatment have required installation of additional units at various times, including gas engines, primary filters, activated sludge units, and sludge lagoons. Figure 1 indicates the manner of treatment of wastes at the present time.

The normal manner of handling waste activated sludge has been to discharge directly to the primary clarifier, causing reduced efficiency, excessively long periods of sludge pumping, shorter digestion periods, and excessive volumes discharged to lagoons.

Excessively high rates of return activated sludge have had to be maintained because of the tendency of sludge to rise or float in the final tanks (1), with the return sludge seldom having more than 0.5 per cent solids. Continually increasing sewage flow has at times caused this problem of handling waste activated sludge to become acute. Such difficulties prompted a search of the field to find some possible means of easing the problem. It appeared obvious that if a feasible and economical means could be found to concentrate the waste activated sludge, it would offer the following advantages:

1. Reduced sludge pumping periods in the primary clarifier.
2. Increased effective digestion capacity.
3. Longer digestion periods.
4. Increased gas production.
5. Reduced heating requirements in the digesters.
6. Increased lagoon capacity.
7. Shorter drying periods in the lagoons.

In the early part of 1950, after a study of available literature and equipment, it was found that there had been developed a continuous solid discharge centrifuge manufactured which discharged through nozzles in the bowl periphery, in place of the older valve-type centrifuge, such as was used by Kraus (2). Available data further indicated that this newer unit was simpler in construction and overcame many of the maintenance problems of the older type unit.

After consultation with engineers of the manufacturer, the city entered into a conditional contract for the purchase of an initial trial unit of 3,000-g.p.h. capacity. The contract called for a concentration of this activated sludge to a range of 4 to 5 per cent. If successful, the city would complete the purchase, with an option of purchasing a second unit, otherwise the initial unit was to be returned to the manufacturer.

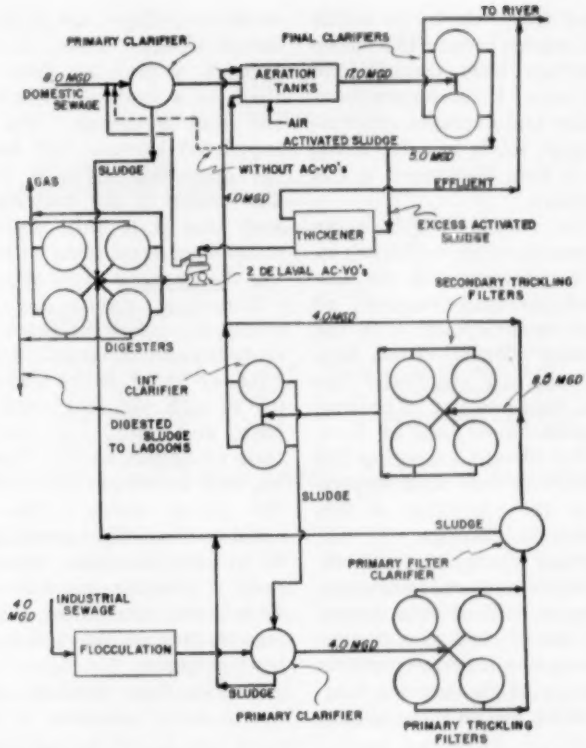


**FIGURE 1.—Flow sheet of Sioux Falls, S. Dak., sewage treatment plant.**

Delivery of the first centrifuge unit was made in mid-year 1950. It was first operated in August 1950 on a trial basis with activated sludge after screening through a 65-mesh vibrating screen capable of handling up to 300 g.p.m. The centrifuge manufacturer supplied a field engineer during the test period to supervise and instruct operating personnel in operating, adjusting and maintaining the equipment.

## The Centrifuge

Bowl construction of the centrifuge used is of the disc type with a set of some 50 conical discs, which are utilized for stratification of the liquor to be clarified. The discs are fitted quite closely together and centrifugal force is applied to the relatively thin film of liquor and solids between the discs. This force throws the denser solid material to the wall of the centrifuge bowl, where it discharges through nozzles located in the periphery. The bowl is equipped with 12 nozzle openings and various numbers of discharge nozzles can be utilized depending on the feed liquor and the desired results. The nozzle bodies have replaceable nozzle inserts of varying bore diameters made of a very hard carbide material. A set of nozzle inserts will last more than six months. This item is relatively inexpensive. The number and size of the solid discharge nozzles used with the centrifuge directly control the sludge concentration for any given feed condition. The limiting factor for higher concentrations is the ability to pump the concentrated sludge from the centrifuges.

The effluent from which the solids are separated travels toward the center of the centrifuge bowl through the intermediate discs. It discharges from the upper cover and averages approximately 250 p.p.m. solids on a dry basis. This effluent is then discharged to the primary clarifiers.

One of the factors which made centrifugal concentration ineffective in the earlier installations was the low efficiency and the large amount of fines returned to the system with the so-called clarified effluent. These fines would build up and eventually the entire system would be out of balance due to the tremendous load of fines. With a clarified effluent averaging 250 p.p.m. no difficulty has been experienced due to the recycling of this effluent through the clarifier.

The centrifuge is complete with 20-hp. built-in drive motors. However, the full 20 hp. is utilized only during the starting period and the average current consumption during operation is approximately 11 hp. per machine. The motors, which are an integral part of the centrifuges, are of the controlled torque design. Power is transmitted through a gear set from the motor shaft to a vertical spindle by which the bowl is driven. The spindle is supported between ball bearings and the operating speed is 6,100 r.p.m. The design of the centrifuge bowl is such that it is quite stable in quite unbalanced conditions without damaging the running parts of the machine.

Consistent results during test periods in 1950 indicated that one centrifuge would handle 3,000 to 4,000 g.p.h. of waste sludge containing from 0.5 to 0.75 per cent solids on a dry basis, and would turn out a concentrate of approximately 5 per cent solids, with an effluent having from 200 to 350 p.p.m. solids. The centrifuge could successfully operate from 48 to 72 hr. between bowl cleanings; however, a cleaning schedule of once in 48 hr. was established. Regular operators require about 2 hr. for each bowl cleaning.

Results thus obtained during several months operation of the experi-

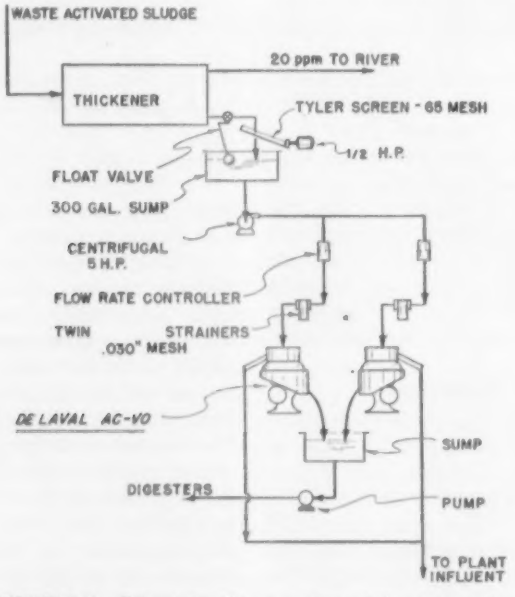


FIGURE 2.—Schematic diagram of centrifuge operation.

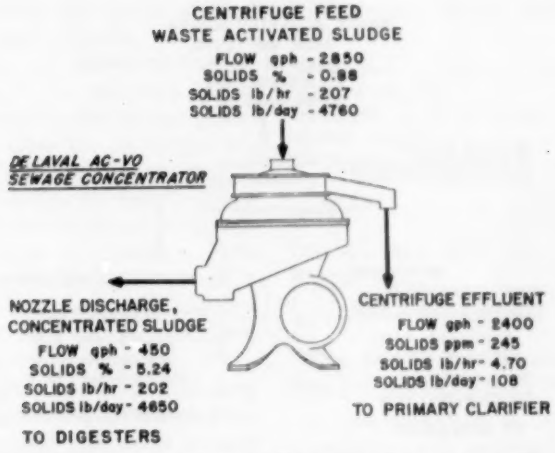


FIGURE 3.—Performance data for centrifuge operation on domestic sewage only.

mental unit were sufficiently convincing, so the city ordered a second unit. Delivery was not made until March 1952, however, due to war conditions.

A permanent building was constructed to house the centrifuges, vibrating screen and auxiliary equipment.

After installation of all equipment the centrifuge manufacturer again furnished a field engineer to supervise initial operation, adjust equipment and assist in securing performance data.

Figure 2 is a schematic diagram of operation of the thickening units as now installed. Because of the excessive return rates necessary, it was deemed advisable to install a thickener ahead of the vibrating screen to partially concentrate the feed.

Control of rates of return sludge to the thickener is by means of automatic rate of flow controller, the rate depending on the ability of the sludge to settle, as measured by the sludge index. Effluent from the thickener averages about 20 p.p.m. and is discharged directly to the river.

The underflow from the thickener is maintained as close to 1 per cent solids as possible and averages about 0.8 per cent with an initial feed of about 0.5 per cent. The use of a thickener might not be justified in many cases, but for the reasons previously stated, seemed indicated here.

The underflow from the thickener passes over a vibrating, 65-mesh wire-cloth screen. The overflow from the screen passes to the flocculator and primary clarifiers. The screen underflow passes into a float-controlled sump, from which it is pumped to the centrifuges through parallel feed lines. Each feed line is equipped with a flow controller and twin pressure strainers with 0.030-in. opening metal screens. The pressure strainers, installed to prevent larger particles from clogging the nozzle openings, are cleaned twice a day as a routine procedure and require about 10 min. time.

Concentrated sludge is discharged from the lower cover of the centrifuge into a sump, from which it is pumped to the digesters by means of a sludge pump. Concentrations are limited to 5 per cent or slightly less on a dry basis because of pumping difficulties. Greater concentrations (up to 6 or 7 per cent) could probably be obtained by proper adjustments; however 5 per cent seems to be the limit of the ability

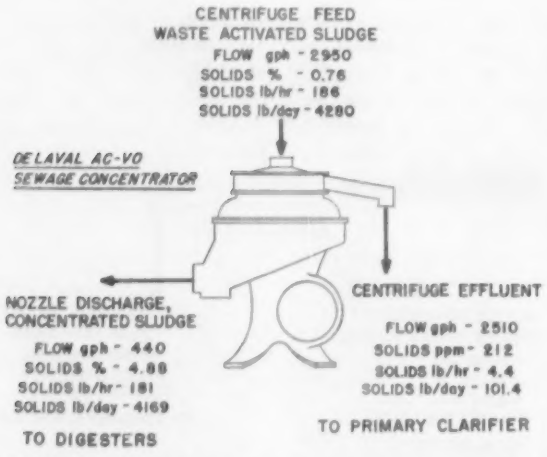


FIGURE 4.—Performance data for centrifuge operation on combined domestic and industrial sewage.

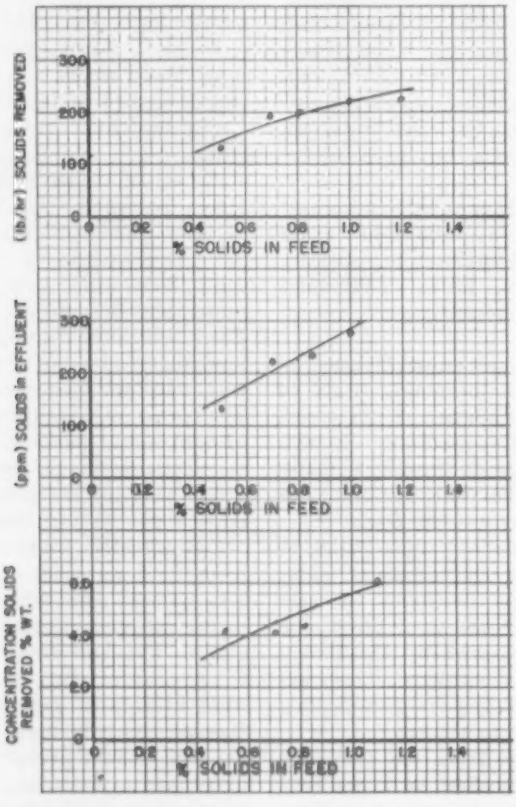


FIGURE 5.—Centrifuge results at 3,000 g.p.h. and varying solids concentration in feed.

of available sludge pumps to successfully handle this material, which becomes extremely gelatinous at concentrations above 4 per cent and is too sluggish to readily enter suction pipes.

The effluent from the centrifuge averages about 250 p.p.m. solids and is discharged directly to the primary clarifiers, with no detrimental effects.

Figure 3 gives performance data when operating with domestic sewage only, showing 84.4 per cent reduction in volume and 97.7 per cent removal of solids from the sludge feed.

Figure 4 gives performance data when operating with a mixture of domestic sewage and industrial wastes, showing 85.2 per cent reduction in volume and 97.3 per cent removal of solids.

Figure 5 shows three curves made up on the basis of the test work. These curves illustrate the performance obtained under various conditions of feed concentration. They were prepared for a constant operating capacity of 3,000 g.p.h. for a single centrifuge and with identical adjustment of the centrifuge for varying feed conditions. In actual practice the centrifuge would have adjustments made which would reflect the percentage of solids in the feed, and the solids concentration discharging from the nozzles would be maintained at approximately 5 per cent. At the same time, the carryover of solids with the effluent would be held below 250 p.p.m.

The estimated cost of the installation was as follows:

| | |
|---|---|
| 2 centrifuge units | $22,000 |
| Building | 3,189 |
| Thickener | 2,454 |
| Controllers | 1,500 |
| Pumps | 1,000 |
| Screen | 500 |
| Piping and labor | 2,500 |
| Total | $33,143 |

The estimated annual operation cost is as follows:

| | |
|---|---|
| Depreciation (15 yr.) | $2,000 |
| Operator (½ time) | 1,800 |
| Power (22 hp. @ $0.01 kw.) | 1,375 |
| Interest (3½%) | 1,155 |
| Maintenance | 500 |
| Total | $6,830 |

This averages $4.37 per ton of solids concentrated.

## Summary

The results of operating experience thus far indicate the following:

1. The centrifuge is capable of concentrating waste activated sludge from 0.8 per cent solids to 5 per cent solids, at rates of 3,000 to 4,000 g.p.h.

2. The effluent contains approximately 250 p.p.m. suspended solids and can be discharged to the primary clarifier.

3. One centrifuge unit of 3,000-g.p.h. capacity operating 22 hr. per day is capable of concentrating the entire waste activated sludge from the plant at present.

4. The volume reduction of waste activated sludge is approximately 85 per cent. The volume of sludge discharged to the lagoons is reduced at least 50 per cent. Digester temperatures are more easily maintained.

5. Sludge pumping periods from clarifiers are reduced from 20 hr. to about 6 hr. per day.

6. Maintenance and operation can be handled by the regular operators.

7. The benefits derived thus far justify the cost of operation.

### References

1. Sawyer, C. N., and Bradney, L., "Rising of Activated Sludge in Final Settling Tanks." *Sewage Works Jour.*, **17**, 6, 1191 (Nov., 1945).

2. Kraus, L. S., and Longley, J. R., "Concentrating Activated Sludge in the Continuous Feed Centrifuge." *Sewage Works Jour.*, **11**, 1, 9 (Jan., 1939).

## DISCUSSION

By L. S. Kraus

*Chemist, Greater Peoria Sanitary District, Peoria, Ill.*

The foregoing paper fits into the pattern of present-day thinking in regard to concentrating sludges prior to digestion. Accomplishing this result effects increased digestion periods, the possibility of increased digester loadings, and higher waste digested sludge solids concentration.

That waste activated sludge can be concentrated to about 5 per cent total solids in a properly designed centrifuge is well known. That this can be accomplished at reasonable rates of sludge discharge accompanied by well-clarified effluent has been definitely established by this paper. The De Laval Separator Co. deserves commendation for the development of this centrifuge. Comparison with the valve-type bowl tested in 1938 at Peoria, Ill., shows that the units capacity has been increased 1.8 times with one-tenth the solids in the clarified effluent. Bowl cleaning has been reduced to one every 48 hr. instead of one each 6 hr.

There is no doubt that the centrifuge can concentrate well-screened activated sludge in the manner described. It remains only to justify its use on the basis of cost and the benefits obtained. It is of interest to note that in the 1938 Peoria study the cost of operation did not warrant the use of centrifuges, whereas the present paper concludes that "the benefits thus far justify the cost of operation." While the dollar cost of operation in both studies is about the same, the present cost is about one-half that of 1938 due to lower dollar purchasing power. Human nature makes it difficult to accept opposite views without discussion. Therefore, accepting the data given by the authors, the following study is made of the applicability of the process for use in the Peoria treatment works.

The total cost of concentrating activated sludge to about 5 per cent solids with centrifuges at Peoria is estimated at $5.93 per ton of dry solids, with an operating cost, excluding fixed charges, of $3.90 per ton. If this cost of $3.90 is compared with the cost of sludge treatment beginning with sludge pumping from the primary settling tanks and including final disposal, the centrifuging of waste activated sludge is found to be a rather expensive operation.

In 1953 the cost of sludge disposal at Peoria was $3.21 per ton of dry sludge solids removed from the sewage. This value does not include fixed charges. If centrifuges had been used this cost would have been substantially increased. The charges for sludge disposal cost in 1953 were about $35,000 for 10,800 tons of dry solids removed from the sewage. At $3.90 per ton, the cost of concentrating waste activated sludge to 5 per cent would have been an added $29,000, making the total cost about $64,000, or $5.93 per ton. This represents an increase of 83 per cent in the cost of sludge disposal.

To justify the use of the centrifuges it is necessary to show a first-cost saving greater than $29,000 amortized over the active life of the centrifuges, after which time a re-appraisal of the costs becomes necessary. For purposes of this computation a 15-year life and 3.5 per cent interest rate are used. In order to justify the added $29,000 annual expenditure a saving in first cost greater than $300,000 must be effected. Considering that the reconstruction cost of the plant digesters is about $625,000, it is probable that the needed first-cost saving would not

be forthcoming, therefore the centrifuge installation would not be considered desirable.

However, it should be borne in mind that the cost of operation of the centrifuge system is largely governed by the cost of labor. In some plants this would not be an added cost, the existing personnel being sufficient to care for the operation of the equipment. If this is the situation the benefits from concentrating the sludge might be such as to warrant the use of the centrifuge system.

To come to a reasonable decision regarding the use of the centrifuge in activated sludge plants the following questions regarding their benefits should be conclusively answered:

1. Is the required digestion capacity reduced, and if so, to what extent?
2. Is gas production increased, and if so, to what extent?
3. Are lagoon or drying bed requirements reduced, and if so, to what extent?

It is not entirely fair to close a discussion by asking almost unanswerable questions. It remains, therefore, for experience to establish the desirability of this added feature to the activated sludge process.

## DISCUSSION

By D. M. Landis

*The DeLaval Separator Co., Poughkeepsie, N. Y.*

The authors' clear and objective presentation of the application of centrifuges to waste activated sludge concentration is particularly opportune for those plants facing load increases similar to Sioux Falls. Also, it ties in with recent developments indicating the possibility of much higher digester loadings when waste sludge concentration can be effectively raised. However, it is felt that the paper's emphasis on costs is misplaced, for the present, until the data are available for more accurate calculations.

The paper clearly pictures the technical features of the operation of the centrifuge on the basis of capacity, solids handling ability, effluent clarity, sludge concentration and reliability. To those unacquainted with previous centrifugal installations for concentration of excess activated sludge, it will be revealing that the only replacement required for the machine has been two sets of nozzle inserts costing approximately $30 per year. The nozzle inserts are the parts subjected to the greatest wear and deterioration, as all of the concentrated solid material passes out through these orifices.

However, while the paper presents a good story on the centrifugal efficiencies, it does not contain sufficient data to justify detailed cost calculations. The extra cost involved and savings, both tangible and intangible, should balance out in favor of the savings. For instance, no plant would try to justify a process that would simply add $4.37 to the cost per ton of solids concentrated. Such a figure by itself is meaningless, as counterbalancing savings must be produced.

Seven definite benefits are listed at the beginning of the paper. In addition, mention is made of the increased primary efficiency obtained by use of the centrifuges. In the summary, four of these benefits are definitely stated as having been attained, but lack of time has definitely prevented the authors from accumulating sufficient data on these benefits. It is hoped that the authors will publish additional data on these savings as it becomes available so that the true op-

erating cost and credits can be accurately apportioned.

Once the increased digester capacities are known as a result of the centrifuge installation, the balance may swing even more in its favor as compared to additional digester and lagoon capacity. Note the implications regarding primary clarification in the statement made by the authors that sludge pumping is reduced from 20 hr. to 6 hr. per day. Also, they have stated that digester temperatures are more easily maintained and the quantity of sludge discharged to lagoons is reduced by at least 50 per cent. Unmentioned is a 50 per cent increase in gas production.

With regard to the cost data included in the paper, three facts should be noted:

1. The authors state that one centrifuge is sufficient, but include two in the capital and operating estimates.
2. Since the authors' estimated yearly cost of operation covers additional costs, a charge for operator should not be included because no extra operators were added.
3. The authors do not mention that when the activated sludge process is operating on domestic sewage only, one centrifuge was required only 38.7 per cent of the time. When the process was operating on combined industrial and domestic sewage, the maximum demand on the centrifuge was 65 per cent of the time. Industrial trickling filter effluent is not always sent to aeration at Sioux Falls, as explained in the authors' reference (1).

This lack of information on centrifuge operating time makes it difficult to deduce from the paper one of the oustanding points in the authors' latest cooperative test work with the centrifuge manufacturer's engineers. This outstanding point is that the amount of suspended solids per day now centrifuged and sent to digestion is less than half the amount previously sent to primary clarification.

### Required Centrifugal Capacity

For a domestic sewage treatment plant now sending its waste activated sludge to primary clarifiers it should be carefully noted that the required centrifugal capacity may be only one-half that of the normal waste sludge volume, since fines will no longer be recycled through primary clarification back to aeration.

In the Sioux Falls installation, after the initial test operations of the first machine, a second centrifuge was purchased. This was for the purpose of handling the known quantity of 6,000 g.p.h. of waste sludge. However, the unusually thin sludge at Sioux Falls, often with less than 0.5 per cent solids, allowed a thickener to halve the volume and double the solids concentration in the centrifuge feed. It was then found that one centrifuge could concentrate this stream to 5 per cent solids and still deliver a satisfactory effluent.

Recent tests conducted at Sioux Falls indicated that when the centrifugal installation was operated full time on domestic sewage the solids in the mixed liquor quite rapidly fell below the optimum value. The one centrifuge removed more than the required amount of solids from the previously required volume of waste activated sludge. Obviously the primary clarifier had previously removed only a portion of the solids from the waste sludge, with the remainder being recycled as fines. When the centrifuge removed 97 per cent of the solids and they were sent directly to digestion, the recycle of fines was eliminated. As a result, the centrifuge hours had to be cut to approximately one-half.

During the initial test work in 1950 the waste sludge sent to primary clarification averaged about 0.45 per cent suspended solids. The same material was supplied to the test centrifuge.

At 6,000 g.p.h. the total amount of suspended solids in the waste sludge amounts to 5,400 lb. per day. Figure 3 shows the centrifuge handling all the waste sludge from domestic sewage amounting to 4,650 lb. per day of suspended solids going to digestion. However, during the period reported the centrifuge operated only 38.7 per cent of total plant time. Thus, $0.387 \times 4{,}650 = 1{,}800$ lb. per day and is the average amount of solids actually sent to digestion. This is quite different from the previously required amount of 5,400 lb. per day sent to primary clarification. As a rough check, comparing 1950 with 1954, $0.387 \times 5{,}400 = 2{,}080$ lb. per day.

With 1,800 lb. of suspended solids per day from 8 m.g.d. of domestic sewage, the single centrifuge's maximum capacity at Sioux Falls is $4{,}650/(1{,}800 \times 8) = 20.6$ m.g.d. For a conservative figure, 18.0 m.g.d. is used. Using this figure excess centrifuge capacity for reserve amounts to $(18 - 8)/8 \times 100 = 125$ per cent. When handling combined industrial and domestic sewage at 12 m.g.d. the operating load on the single centrifuge is increased by only 50 per cent. Therefore, a reserve capacity of 75 per cent is still available.

In industrial practice, stand-by centrifuges are normally not installed except in large multiple installations where 5 or 10 per cent of over-all centrifuge capacity is installed as stand-by. Normally a stock of mechanical spare parts will allow the plant maintenance men to quickly restore production; if bowl trouble should develop, loan bowls are available from the manufacturer.

## Costs

Based on existing information it is felt that the following is the only justifiable rough cost analysis that can be used for the present:

*Capital*

Per centrifuge, including building, controls and all accessories, $18,950.

At Sioux Falls for 8.0 m.g.d. domestic sewage only $18,950/8 = $2,370 per m.g.d.

At Sioux Falls for 12.0 m.g.d. domestic and industrial sewage, $18,950/12 = $1,580 per m.g.d.

For other plants if centrifuge's full capacity of 18 m.g.d. is utilized, $18,950/18 = $1,051 per m.g.d.

These values will be a good deal less for multiple installations of five or more machines.

*Operating Costs* (Domestic Sewage Only)

1. At Sioux Falls for 38.7 per cent time of operation of centrifuge, $2,570 per year for operation of one centrifuge. Operating cost per day = $2,570/(8 × 365) = $0.87 per m.g., or $6.96 per day. (In arriving at $2,570 as operating cost for one centrifuge, any charge for an operator is eliminated, a depreciation charge based on 15 years on the amount of $18,950 is used, a true figure of operating time in computing power cost is used and, in view of Sioux Falls actual experience, the maintenance is reduced to $250.)
2. For 100 per cent utilization of centrifuge capacity, or 18-m.g.d. capacity, and including part of an operator's time, operating cost per day = $3,539/(18 × 365) = $0.54 per m.g., or $9.72 per day.
   (In industry one centrifuge operator will handle from 10 to 30 centrifuges.)

If handled with reasonable caution the foregoing figures will allow an immediate but rough estimate of capital outlay and additional operating costs for any domestic activated

sludge sewage plant. If the solids in the waste sludge actually going to digestion are known or can be closely estimated, the benefits of increased digester capacity, reduced sludge pumping, increased lagoon capacity, etc., can be roughly estimated and balanced against the cost of the centrifuges. Capital outlay for centrifuges as compared to additional digesters, lagoons, etc., can also be determined.

For those plants now sending waste sludge to primary clarifiers, it should be noted that the authors find sludge pumping periods reduced from 20 to 6 hr. This is much greater than was expected and indicates considerable improvement which is as yet unmeasured. A factor not touched upon is the large savings in space requirements where centrifuges are utilized. For those plants having little room for expansion and facing insufficient digester capacity or impaired primary efficiency, the use of centrifuges from the viewpoint of space savings could be equally as important as the economic savings.

## PUBLIC RELATIONS MOVIE ON SEWERS

The many benefits which sanitary sewers bring to a community are clearly and interestingly told in a new movie produced by the Clay Products Association. The 20-min. colored film is titled "Sewers—Guardian of Community Health."

The film shows the importance of adequate sewerage and sewage treatment in communities of all sizes. Such dangers as unrestricted use of septic tanks, improper treatment, and stream contamination are illustrated and commented upon.

The economy of sewers and the many other advantages which they offer a community are forcefully presented in a way that can be understood by the layman as well as the city official.

The film, sponsored by the Clay Products Association, is offered as a community service. It is promotional only insofar as stressing the clear-cut need for sanitary sewerage.

The movie is ideal for showing, at no cost or obligation, to civic, service, and fraternal groups and conventions, and other organizations interested in improving the sanitary facilities of their communities.

Further information regarding the new movie, and reservations for showing it, can be obtained by writing to the Clay Products Association, 100 North LaSalle Street, Chicago 2, Ill.

# EFFECT OF RECIRCULATION ON TRICKLING FILTER PERFORMANCE

By J. H. Sorrels and P. J. A. Zeller

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The authors have previously reported on the purification of settled sewage by filtration through a standard-rate trickling filter (10). Many sewage treatment plants employ recirculation of filtered sewage as a means of increasing efficiency of treatment. Recirculation ratios (volume of filtered sewage per volume of settled sewage applied to the filter) vary from 1:1 to 1:10, or even higher. In most cases recirculation ratios are between one and two. Above a ratio of two the increased effect obtained is small and the economy is questionable. The number of times sewage passes through a filter when recirculation is used is known as the recirculation factor. This is obtained by the generally accepted equation:

$$F = \frac{1 + R/I}{(1 + 0.1\,R/I)^2}$$

As Mohlman *et al.* (9) state, "The recirculation factor increases with the recirculation ratio $R/I$ until a maximum value is obtained." This maximum value is obtained when $R/I = 8$. When $R/I = 2$, $F = 2.08$; when $R/I$, $= 8$, $F = 2.78$.

Many studies of recirculation on trickling filters have been made. Bachmann (1) reports on biofilters in California, Mohlman *et al.* (7)(9) report on filters in army camps during World War II, and Greeley (6) reports on municipal plants. In all these cases the sewages treated, the loading rates, and the recirculation ratios varied. The general comparisons made of the results are excellent in showing what can be accomplished in sewage treatment by recirculation, and are especially good for design purposes. Nevertheless, the results obtained by different filters should be compared with caution to predict what one filter would do under a different set of conditions. In other words, changing the recirculation ratio on a filter does not necessarily mean that treatment results will be the same as those of some other filter with the same recirculation ratio. Other factors, such as organic load, hydraulic rate, and temperature, will affect the degree of treatment and should be considered. The present study attempts to describe the effects of the first two of these factors, with recirculation ratios of one and two, using the same sewage and the same filters.

## Experimentation

The objectives of the experiments have been: to study the effects upon filter performance of (a) organic loading as expressed in terms of B.O.D.; (b) organic loading as expressed in terms of volatile suspended solids; and (c) the hydraulic rate expressed in terms of million gallons per acre per day.

The filters used in this work have been previously described (10). The loading rates were approximately 500, 800, 1,200, and 1,750 lb. of 5-day B.O.D. per acre-foot per day. For the recirculation ratio of one the hydraulic rates were 3.5, 5.0, 7.7, and 11.5 m.g.a.d., respectively; for the ratio of two, the hydraulic rates were 5.0, 7.4, 11.1, and 16.6 m.g.a.d., respectively.

TABLE I.—Condensed Summary of Filter Results with 1 : 1 and 2 : 1 Recirculation Ratios

| Determination | 1:1 Recirculation Ratio | | | 2:1 Recirculation Ratio | | |
|---|---|---|---|---|---|---|
| | Max. | Min. | Av. | Max. | Min. | Av. |
| Applied settled sewage and recyclate: | | | | | | |
| B.O.D. | 147 | 52 | 108 | 109 | 41 | 77 |
| Vol. susp. sol. | 102 | 33 | 67 | 77 | 32 | 54 |
| Nitrate | 5.2 | 0.3 | 3.1 | 6.8 | 0.3 | 3.2 |
| Filter No. 1: | | | | | | |
| B.O.D. | 48 | 17 | 34 | 46 | 13 | 28 |
| Vol. susp. sol. | 33 | 5 | 20 | 46 | 9 | 22 |
| Nitrate | 10 | 1.0 | 5.7 | 10 | 1.0 | 5.8 |
| Filter No. 2: | | | | | | |
| B.O.D. | 63 | 12 | 37 | 53 | 14 | 31 |
| Vol. susp. sol. | 42 | 7 | 25 | 38 | 8 | 25 |
| Nitrate | 10 | 0.7 | 5.3 | 10 | 0.5 | 4.4 |
| Filter No. 3: | | | | | | |
| B.O.D. | 63 | 21 | 42 | 54 | 16 | 34 |
| Vol. susp. sol. | 47 | 11 | 30 | 49 | 12 | 28 |
| Nitrate | 6 | 1.0 | 3.4 | 10 | 0.4 | 3.3 |
| Filter No. 4: | | | | | | |
| B.O.D. | 75 | 22 | 48 | 80 | 19 | 46 |
| Vol. susp. sol. | 50 | 12 | 34 | 49 | 16 | 35 |
| Nitrate | 5 | 0.5 | 2.4 | 4.5 | 0.2 | 1.3 |

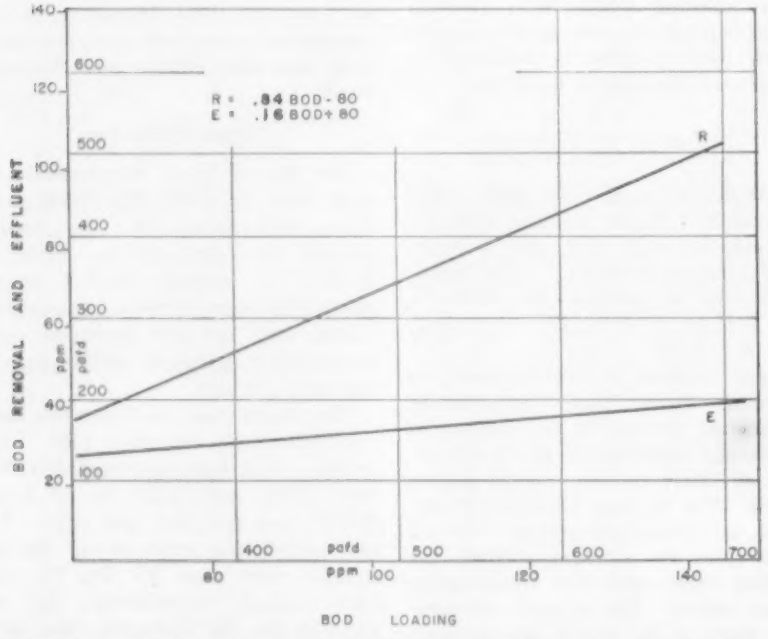


FIGURE 1.—B.O.D. performance, filter No. 1, recirculation ratio 1:1, hydraulic rate 3.5 m.g.a.d.

Settled sewage from the Agricultural and Mechanical College of Texas treatment plant was mixed with the final effluent and applied to the filters. The hydraulic rate of each was measured independently. The rates were checked hourly and adjusted if necessary. Samples were taken hourly from 8:00 AM to 5:00 PM, composited, and stored at a low temperature until analyses were completed. Twenty-six sets of samples were taken at the ratio of one, and 47 sets were taken at the ratio of two. All analyses were made according to "Standard Methods" (11). Table I is a condensed summary of these results.

## Results

Performance of these filters was based on removal of B.O.D. and volatile suspended solids, and the production of nitrates. The data obtained were analysed and equations for removal determined by the customary statistical methods (2). Figures 1 to 4 show the B.O.D. performance at a 1:1 recirculation ratio, Figures 5 to 8 at a 2:1 ratio. Figures 9 to 12 show the volatile suspended solids performance at a 1:1 ratio, Figures 13 to 16 at a 2:1 ratio. Figure 17 shows the nitrate performance at both recirculation ratios and without recirculation.

In Figures 1 to 8 it can be seen that as the B.O.D. loading increases, removal of B.O.D. increases. The B.O.D. of the effluent also increases. At a recirculation ratio of one the reduction rate is fairly constant, the slopes varying from 0.68 to 0.84. At a recirculation ratio of two the reduction rate is fairly constant for the first three filters, varying from 0.52 to 0.59 corresponding to a maximum B.O.D. loading of about 1,200 lb. per acre-foot per day. At loadings above this amount the reduction rate drops

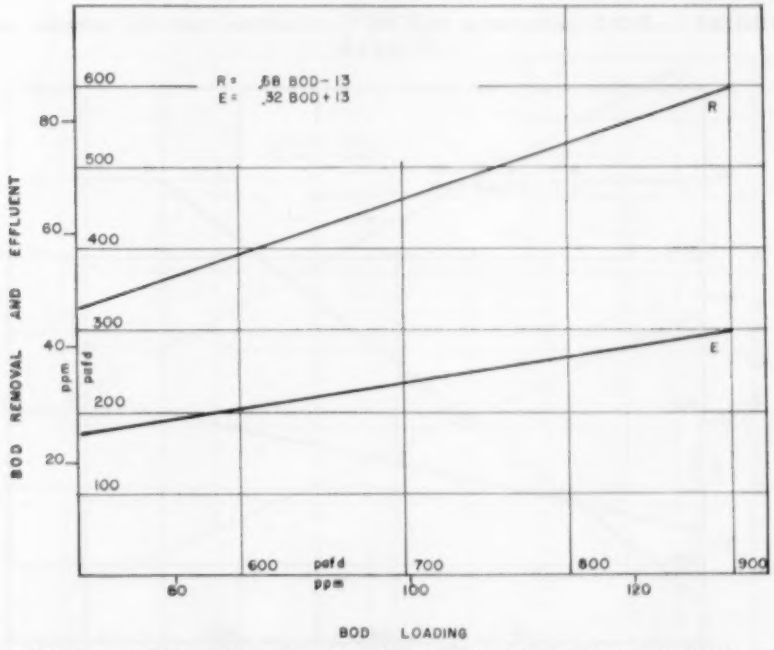


FIGURE 2.—B.O.D. performance, filter No. 2, recirculation ratio 1:1, hydraulic rate 5 m.g.a.d.

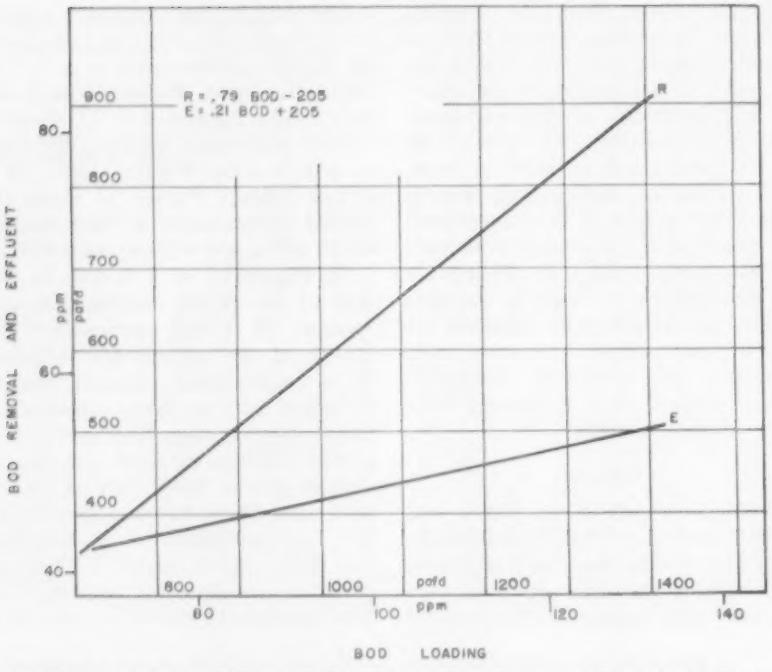


FIGURE 3.—B.O.D. performance, filter No. 3, recirculation ratio 1:1, hydraulic rate 7.7 m.g.a.d.

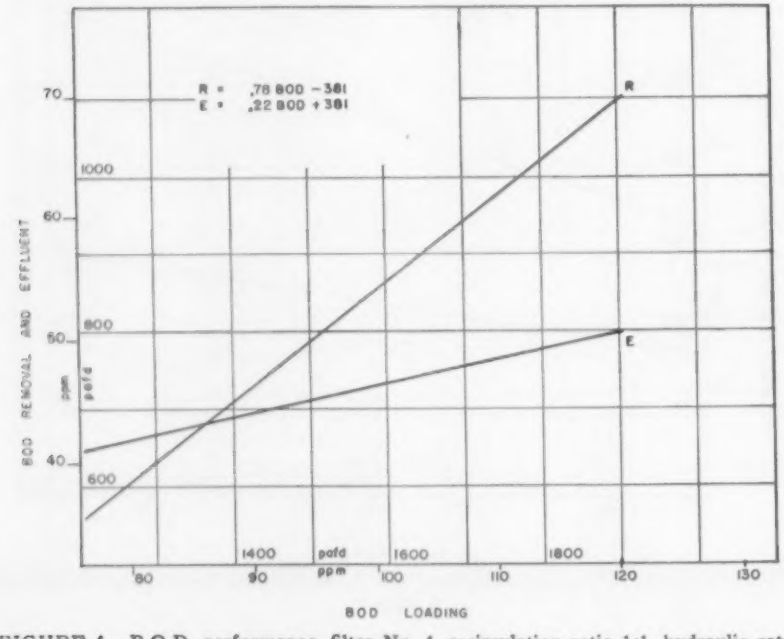


FIGURE 4.—B.O.D. performance, filter No. 4, recirculation ratio 1:1, hydraulic rate 11.5 m.g.a.d.

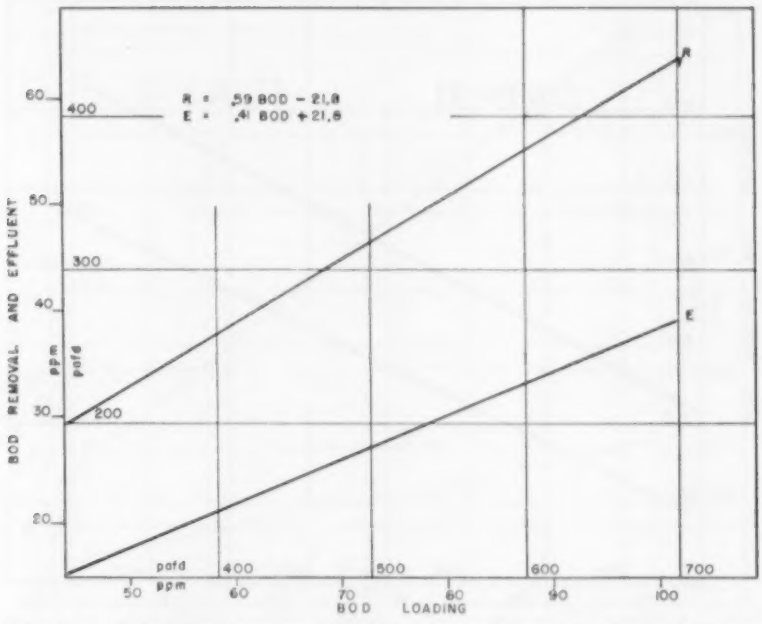


FIGURE 5.—B.O.D. performance, filter No. 1, recirculation ratio 2:1, hydraulic rate 5 m.g.a.d.

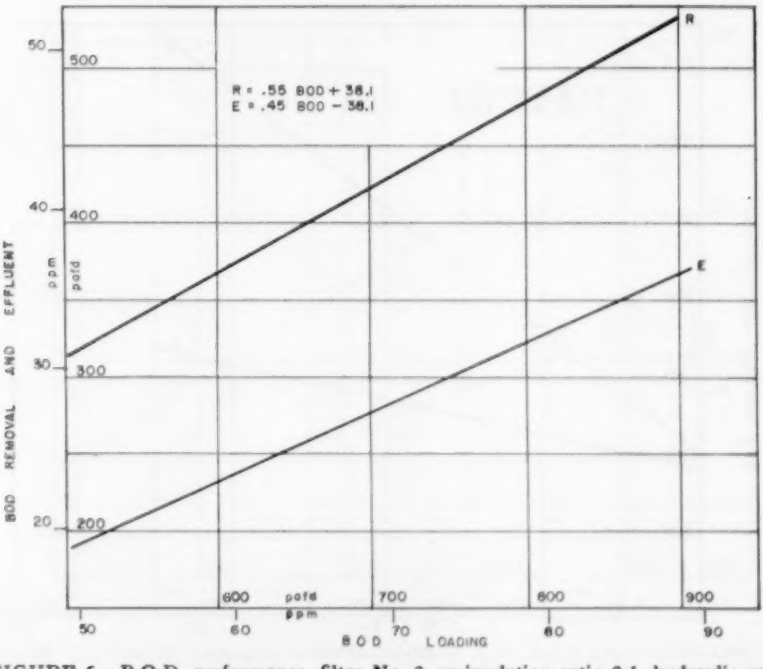


FIGURE 6.—B.O.D. performance, filter No. 2, recirculation ratio 2:1, hydraulic rate 7.4 m.g.a.d.

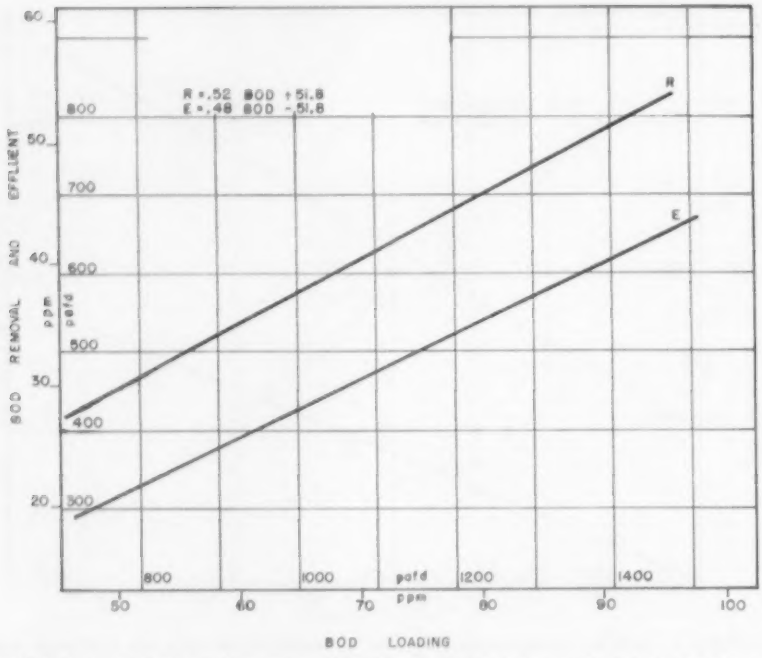


FIGURE 7.—B.O.D. performance, filter No. 3, recirculation ratio 2:1, hydraulic rate 11.1 m.g.a.d.

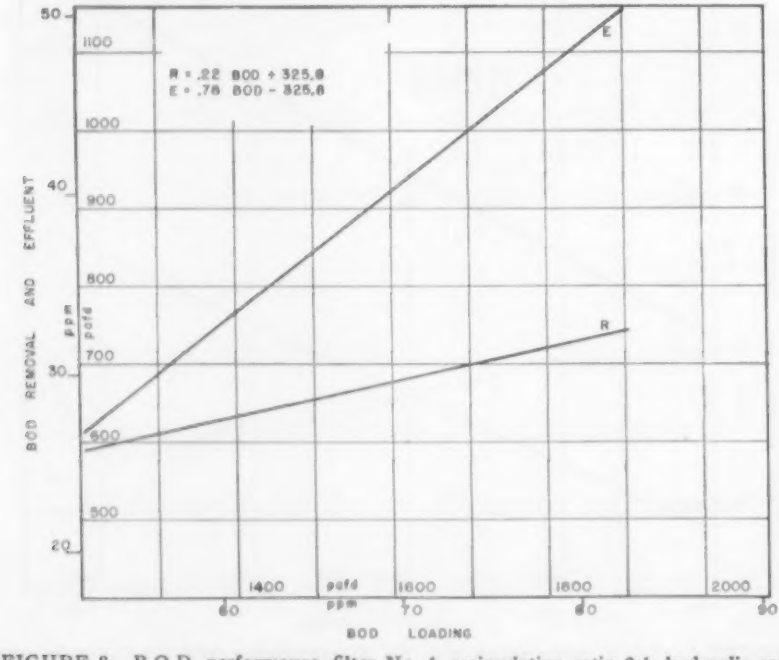


FIGURE 8.—B.O.D. performance, filter No. 4, recirculation ratio 2:1, hydraulic rate 16.6 m.g.a.d.

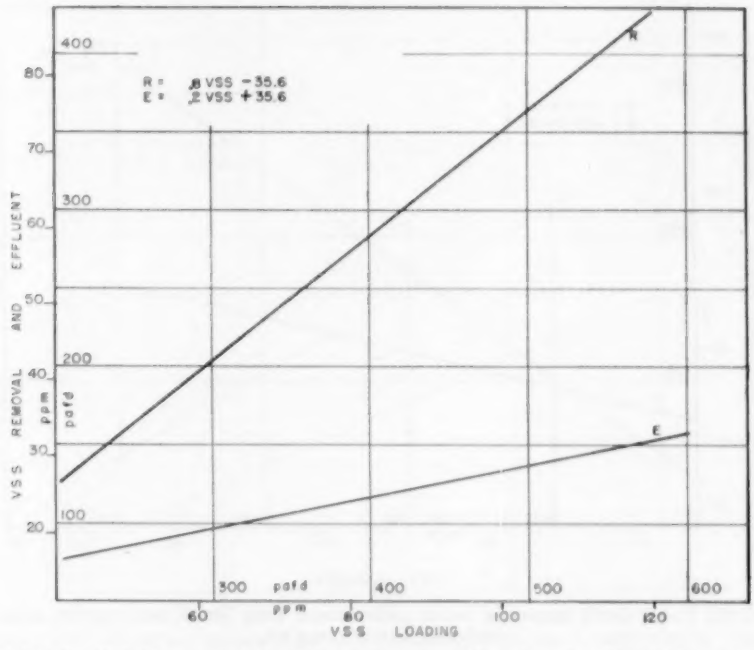


FIGURE 9.—Volatile suspended solids performance, filter No. 1, recirculation ratio 1:1, hydraulic rate 3.5 m.g.a.d.

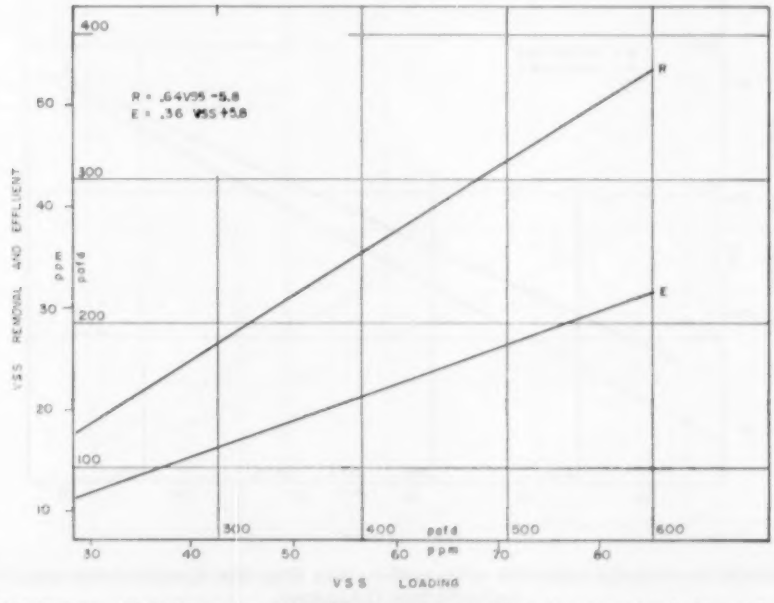


FIGURE 10.—Volatile suspended solids performance, filter No. 2, recirculation ratio 1:1, hydraulic rate 5 m.g.a.d.

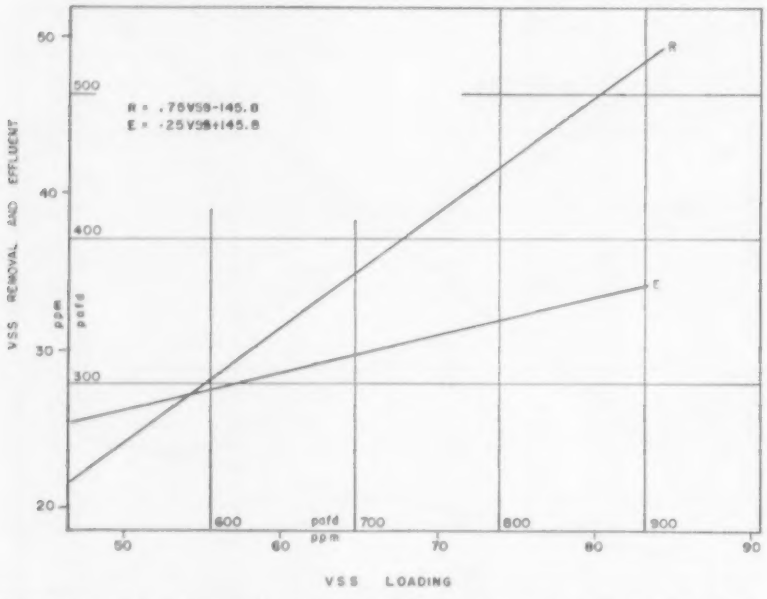


FIGURE 11.—Volatile suspended solids performance, filter No. 3, recirculation ratio 1:1, hydraulic rate 7.7 m.g.a.d.

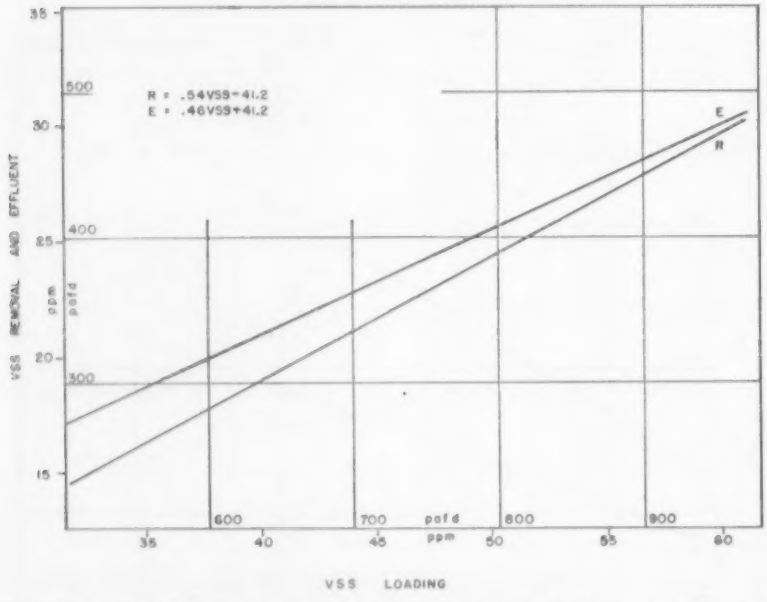


FIGURE 12.—Volatile suspended solids performance, filter No. 4, recirculation ratio 1:1, hydraulic rate 11.5 m.g.a.d.

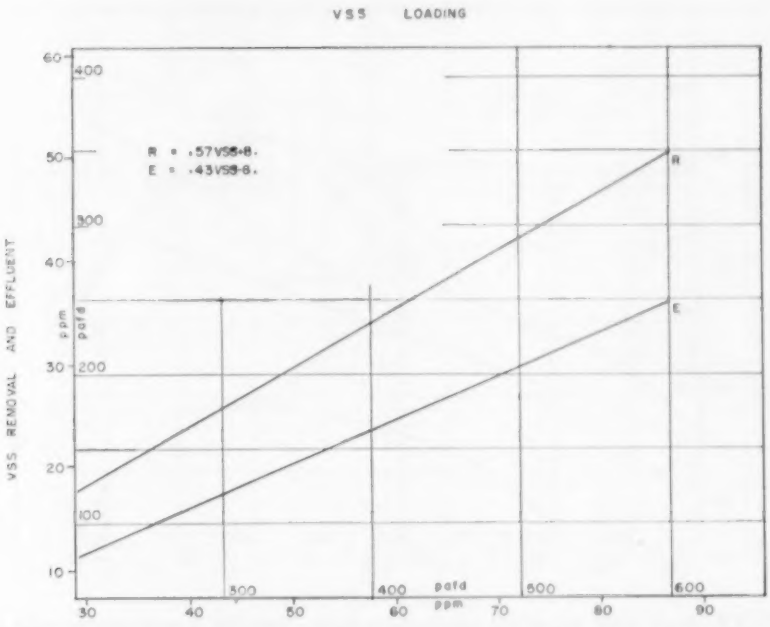


FIGURE 13.—Volatile suspended solids performance, filter No. 1, recirculation ratio 2:1, hydraulic rate 5 m.g.a.d.

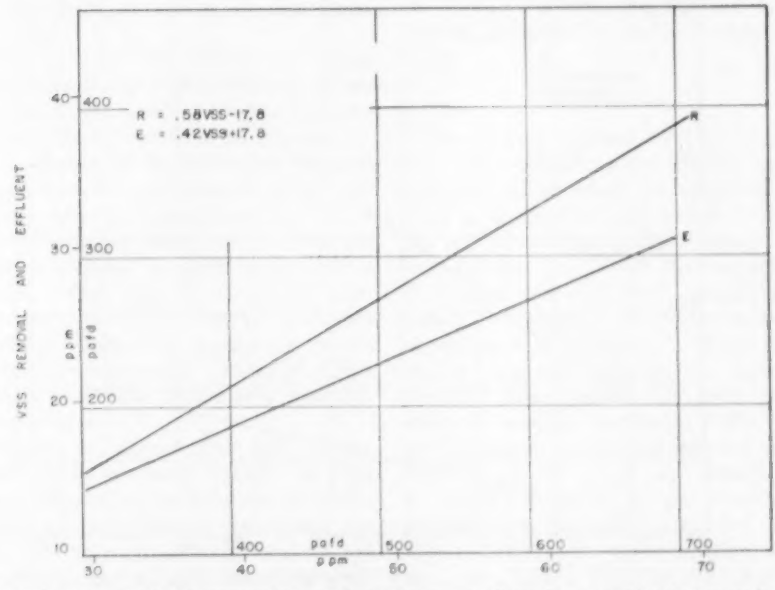


FIGURE 14.—Volatile suspended solids performance, filter No. 2, recirculation ratio 2:1, hydraulic rate 7.4 m.g.a.d.

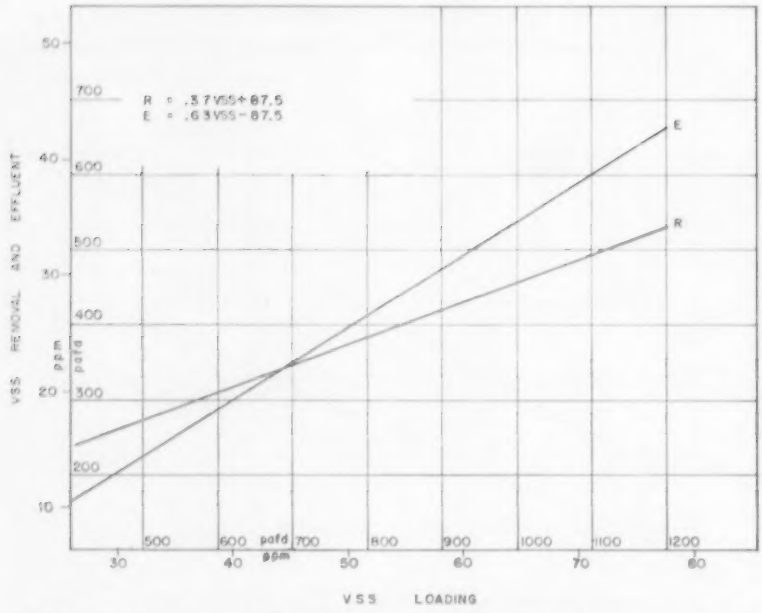


FIGURE 15.—Volatile suspended solids performance, filter No. 3, recirculation ratio 2:1, hydraulic rate 11.1 m.g.a.d.

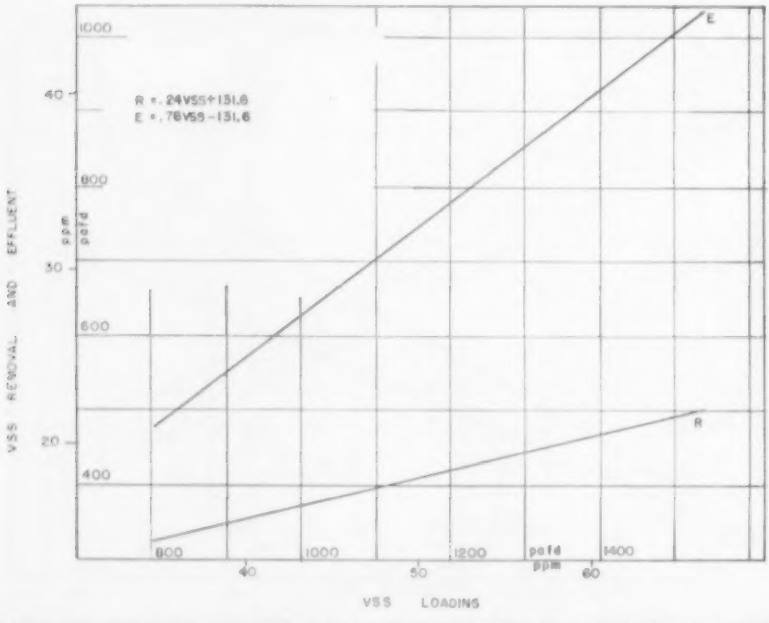


FIGURE 16.—Volatile suspended solids performance, filter No. 4, recirculation ratio 2:1, hydraulic rate 16.6 m.g.a.d.

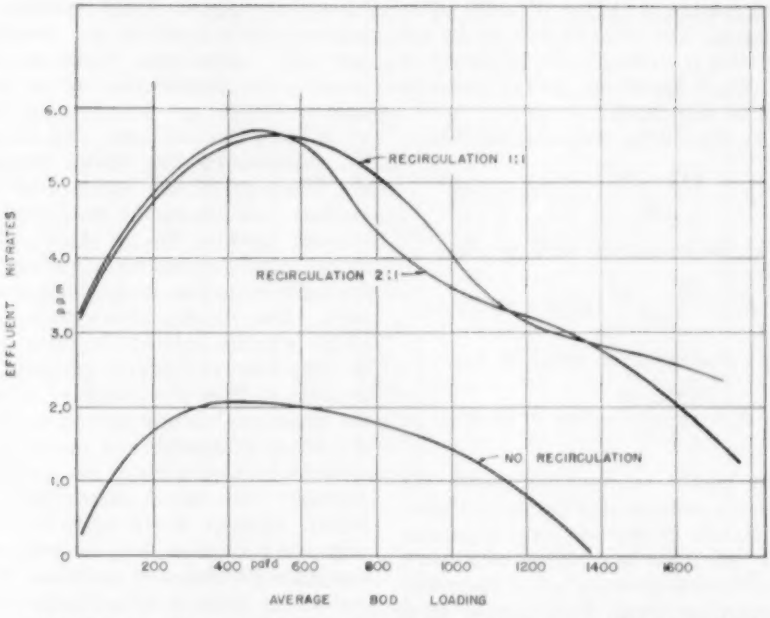


**FIGURE 17.—Nitrate performance with no recirculation and with 1:1 and 2:1 recirculation ratios.**

considerably, as shown by the slope of 0.22.

This change in B.O.D. reduction rate is probably due primarily to the increased hydraulic rate and the consequent decreased time of contact.

In Figures 9 to 16 it can be seen that removal and effluent solids increase with increased loading. Considerably more variation in reduction rate is noticed at both recirculation ratios. The rate of reduction consistently decreases with increased loading. This drop is sharper in the 2:1 ratio than in the 1:1 ratio. This also is likely due to the increased hydraulic rate.

Figure 17 shows that with no recirculation, nitrates appear in the filter effluent up to loadings of about 1,200 lb. B.O.D. per acre-foot per day. With recirculation, nitrates are present in the applied recyclate. Additional nitrates are formed at both ratios up to loadings of about 1,200 lb. B.O.D. Above this loading some nitrate is actually lost through the filter.

## Discussion

The usual method (1)(4)(6)(7)(9) for determining the loading on a trickling filter when recirculation is used is to consider only the B.O.D. of the settled sewage applied; others (3) include the B.O.D. of the recyclate. For plant operation and over-all efficiency of treatment the former method is entirely satisfactory. When this method is used, however, the filter is credited with considerably more work than it actually performs. For example, assume a settled sewage with a B.O.D. of 192 p.p.m. and an effluent of 20 p.p.m. used as the recyclate. With a recirculation ratio of one the actual B.O.D. of the applied sewage is $(192 + 20)/2 = 106$ p.p.m., whereas with a recirculation ratio of two the actual B.O.D. of the ap-

plied sewage is $[192 + (2 \times 20)]/3 = 77$ p.p.m. The effect of dilution by the recyclate is obvious. The efficiency of the filter based on B.O.D. removal may be calculated:

(a) Excluding recirculation load

$$E = \frac{192 - 20}{192}(100) = 89.6\%$$

(b) Recirculation ratio of one

$$E = \frac{106 - 20}{106}(100) = 81.1\%$$

(c) Recirculation ratio of two

$$E = \frac{77 - 20}{77}(100) = 74.0\%$$

With higher recirculation ratios the efficiency reduces still further. Unless the B.O.D. of the recyclate is considered, the filter is credited with work which it really does not accomplish. A study of actual performance of a trickling filter based on B.O.D. removal, volatile suspended solids removal and nitrate production must include the load contributed by the recyclate in order to obtain a materials balance through the filter. Throughout this report the materials balance method has been used; that is, the B.O.D. applied to the filter is calculated from the B.O.D. in the recyclate and the B.O.D. in the settled sewage. Hydraulic rates include both recyclate and settled sewage.

It has been pointed out (Figures 1 to 8) that the B.O.D. removal increases with increased loading. The rate of reduction, however, decreases as the loading increases, and although more organic matter is removed by the filter, the effluent from the filter becomes increasingly poorer at the higher loadings. This is apparent at both the 1:1 and 2:1 ratios.

Further evidence of deterioration of effluent with increased loading is noticeable in the nitrate performance. Grantham (5) in Florida found evidence that nitrate production decreased sharply at B.O.D. loadings of approximately 1,400 lb. per acre-foot per day. Similarly, Mohlman (8) found active nitrification up to loadings of 720 lb. per acre-foot per day at military installations. In Figure 17, a horizontal line drawn through the intercept of the curve with the vertical axis shows the true production of nitrates by the filter. The figure clearly shows more nitrates in the effluent when recirculation was used. But it also shows that most of the nitrates entered the filter with the recyclate, and cannot properly be credited to filter performance. Unless the materials balance method is used, this effect is masked, and the filter is credited with work it did not perform. Actually the curves show that at B.O.D. loadings above 1,200 lb., not only were nitrates not formed, but also some nitrates were reduced. This is contrary to the accepted theory that nitrates are not used as a source of oxygen as long as dissolved oxygen is present. No data are presented, but the filter effluents definitely were not devoid of dissolved oxygen. As far as is known, this phenomenon has not previously been reported. Many organisms in sewage can reduce nitrates, and might do so at a low concentration of dissolved oxygen. It is also possible that there are anaerobic pockets within the filter, where nitrate reduction could proceed readily.

Figures 9 to 16 show filter performance in regard to volatile suspended solids. The same general trends are apparent as were shown with respect to B.O.D. performance. There was, however, no correlation between B.O.D. removal and volatile suspended solids removal.

In an attempt to evaluate the effect of hydraulic rate and organic loading on 6-ft. trickling filters, a summary of the data is presented in Table II. For convenience the data are arranged in increasing order of hydraulic rate. Although the table contains data from

TABLE II.—Effect of Organic Loading on B.O.D. Removal by Trickling Filter 6 Ft. Deep

| Hydraulic Rate | | B.O.D. Loading | | B.O.D. Removal | | Effluent B.O.D. | | | Calc. B.O.D. Removal (lb./a.-ft./day) | Recirc. Ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| (m.g.a.d.) | Increase (%) | (lb./a.-ft./day) | Increase (%) | (lb./a.-ft./day) | (%) | (lb./a.-ft./day) | Increase (%) | (p.p.m.) | | |
| 1.6 | — | 399 | — | 306 | 76.7 | 93 | — | 42 | 356 | 0 |
| 2.3 | — | 582 | — | 433 | 74.4 | 149 | — | 47 | 453 | 0 |
| 3.5 | — | 521 | — | 357 | 68.5 | 164 | — | 34 | 380 | 1 |
| 3.6 | 3 | 888 | 70 | 624 | 70.3 | 264 | 60 | 53 | 612 | 0 |
| 5.0 | — | 530 | — | 337 | 63.6 | 193 | — | 28 | 344 | 2 |
| 5.0 | 0 | 786 | 48 | 502 | 63.9 | 284 | 47 | 41 | 508 | 1 |
| 5.4 | — | 1,322 | — | 805 | 60.9 | 517 | — | 69 | 839 | 0 |
| 7.4 | — | 785 | — | 468 | 59.6 | 317 | — | 31 | 438 | 2 |
| 7.7 | 4 | 1,150 | 46 | 708 | 61.6 | 442 | 39 | 41 | 664 | 1 |
| 11.1 | — | 1,187 | — | 664 | 55.9 | 523 | — | 34 | 591 | 2 |
| 11.5 | 4 | 1,711 | 44 | 953 | 55.7 | 758 | 45 | 47 | 914 | 1 |
| 16.6 | — | 1,773 | — | 709 | 40.0 | 1,064 | — | 46 | 809 | 2 |

a former study with no recirculation (10) as well as from two recirculation ratios, the organic loading on the filters includes that derived from the recyclate if used, and performance is based upon the total B.O.D. loading. Examination of Table II shows a trend as to the effect of organic loading. It will be noted that with approximately the same hydraulic rate, the percentage removal of B.O.D. is about the same, even with considerable difference in organic loading. It is obvious that with higher organic loadings more B.O.D. will pass through the filter, resulting in a higher B.O.D. concentration in the effluent. For example, with a hydraulic rate of 5.0 m.g.a.d., as B.O.D. loading increased from 530 lb. at a recycling ratio of two, to 786 lb. per acre-foot per day at a recycling ratio of one, the percentage removal is practically constant at 63 per cent. Of particular interest is the fact that as the loading increased 48 per cent the amount of B.O.D. passing out in the effluent increased 47 per cent. Thus, as the load increased the filter did more work, but at the cost of discharging a stronger effluent.

For convenience, some of the data

TABLE III.—Effect of Hydraulic Rate on B.O.D. Removal by Trickling Filter 6 Ft. Deep

| Hydraulic Rate | | B.O.D. Loading | | B.O.D. Removal | | Effluent B.O.D. | | | Recirc. Ratio |
|---|---|---|---|---|---|---|---|---|---|
| (m.g.a.d.) | Increase (%) | (lb./a.-ft./day) | Increase (%) | (lb./a.-ft./day) | (%) | (lb./a.-ft./day) | Increase (%) | (p.p.m.) | |
| 3.5 | | 521 | — | 357 | 68.5 | 164 | | 34 | 1 |
| 5.0 | 43 | 530 | 2 | 337 | 63.6 | 193 | 18 | 28 | 2 |
| 5.0 | | 786 | — | 502 | 63.9 | 284 | | 41 | 1 |
| 7.4 | 48 | 785 | 0 | 468 | 59.6 | 317 | 12 | 31 | 2 |
| 7.7 | | 1,150 | — | 708 | 61.6 | 442 | | 41 | 1 |
| 11.1 | 44 | 1,187 | 3 | 664 | 55.9 | 523 | 18 | 34 | 2 |
| 11.5 | | 1,711 | — | 953 | 55.7 | 758 | | 47 | 1 |
| 16.6 | 36 | 1,773 | 4 | 709 | 40.0 | 1,064 | 40 | 46 | 2 |

FIGURE 18.—Chart for figuring performance of 6-ft. deep filter.

in Table II have been regrouped according to organic loading (Table III). At approximately the same organic loading the percentage removal decreases as the hydraulic rate is increased. This results in more B.O.D. passing through the filter because of the greater volume of liquid. The B.O.D. concentration in the effluent, however, is decreased. For example, with an organic load of 521 to 530 lb. B.O.D., the hydraulic rate increased from 3.5 m.g.a.d. to 5.0 m.g.a.d., or 43 per cent. Removal decreased from 357 lb. to 337 lb. B.O.D. per acre-foot per day, or 8 per cent; the total B.O.D. in the effluent increased from 164 lb. to 193 lb. per acre-foot per day, or 18 per cent, and the effluent B.O.D. concentration decreased from 34 to 28 p.p.m., or 21 per cent. In spite of the decrease in effluent B.O.D. concentration the pollution load discharged by the filter was greater.

The ultimate effect of recirculation is a lower B.O.D. discharged, but the work accomplished by the filter can only be determined by the total loading on the filter.

Assuming a linear relationship, an equation was developed by statistical analysis. This is presented for con-

venience in the form of a nomogram (Figure 18). The nomogram has been confined to the range covered in this study and is specifically for filters of 6-ft. depth. The equation was checked with observed data with an average deviation of 6 per cent. It has been checked with some published data from other plants with good agreement within the range of the nomogram. A similar equation was developed for the volatile suspended solids performance. Comparable results were obtained, but the nomogram is not presented here because performance is most commonly based upon removal of B.O.D.

## Summary

Four identical 6-ft. experimental filters were operated over a period of three years. Settled sewage and final effluent from the treatment plant of the A. and M. College of Texas were applied at recirculation ratios of one and two. Composite samples were taken and hydraulic rates checked hourly from 8:00 AM to 5:00 PM. Applied loadings varied from 500 to 1,750 lb. of 5-day B.O.D. per acre-foot per day. All computations were based on a materials balance of the item considered. Within the range of this study, organic loading and hydraulic rate were found to have significant effects on filter performance.

## Conclusions

1. As the B.O.D. loading on a trickling filter increases from 400 to 1,750 lb. per acre-foot per day either with or without recirculation:

(a) The total amount of B.O.D. removed by the filter increases from 300 to 950 lb. per acre-foot per day.

(b) The B.O.D. removal decreases from 77 per cent at 400 lb. to 40 per cent at 1,750 lb. per acre-foot per day, resulting in a poorer quality effluent ranging from 93 to 1,064 lb. per acre-foot per day.

2. Little correlation exists between B.O.D. removal and volatile suspended solids removal.

3. With recirculation, more nitrates are present in the effluent than without recirculation. Most of the nitrates, however, come from the recyclate. At loadings above 1,200 lb. per acre-foot per day nitrates are reduced in the filter (Figure 17).

4. Organic loading, measurd in pounds of B.O.D. per acre-foot per day has a significant effect upon filter performance. At any given hydraulic rate with increased B.O.D. loading:

(a) Change in percentage removal of B.O.D. is less than 3 per cent.

(b) Absolute removal of B.O.D. increases in proportion to the B.O.D. loading.

(c) The quality of the effluent deteriorates and the total amount of pollution discharged increases in proportion to the B.O.D. loading.

5. Hydraulic rate, measured in million gallons per acre per day, has a significant effect on filter performance. At any given B.O.D. loading, an increase in the hydraulic rate results in (a) a decrease in percentage removal of B.O.D., which becomes greater with higher loadings; (b) a decrease in absolute B.O.D. removal, which becomes greater at higher loadings; (c) a consistent decrease in the B.O.D. concentration remaining in the effluent, roughly inversely proportional to the hydraulic rate; and (d) an increase in the absolute amount of pollution discharged in the effluent.

6. An equation has been developed to illustrate the relation between B.O.D. loading, hydraulic rate, and B.O.D. removal. This equation, $R = 147 - 0.64$ B.O.D. $- 28.5\ H$, is presented as a nomogram (Figure 18) for a 6-ft. filter.

7. Removal of volatile suspended solids and effluent quality follow the same trend as for B.O.D.

8. Air temperature and barometric pressure seem to have no significant effect upon filter performance.

9. Dilution is an important factor in recirculation.

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FEDERATION HEADQUARTERS OFFICE MOVED

By the end of April 1955, the Federation headquarters and publication office will be moved from its present location in Champaign, Ill., to new quarters in Washington, D. C. See page 513 for details.

# TWO-STAGE OPERATION OF ACTIVATED SLUDGE PLANTS

By Karl Imhoff

*Consulting Engineer, Essen, Germany*

In the treatment of sewage by the conventional activated sludge process, part of the activated sludge concentrated by secondary sedimentation is returned to the aeration tanks as the biological purification medium. This part is called "return sludge." The remainder is disposed of as "excess sludge." Normally, excess-sludge is delivered to digestion tanks together with the primary sludge. The digested sludge is generally dried.

The conventional process, as practiced for about 40 years, does not attempt to utilize the cleansing power of the excess sludge. Instead, this power is destroyed in digestion tanks. An additional disadvantage is the extremely high water content of the excess sludge and the unnecessarily large space required for its digestion: usually three times the space needed for primary sludge.

These disadvantages can be avoided by dividing the activation process into two stages. Incidentally, the terms "two-stage" and "multi-stage" should be used only when each stage includes its own areation tank *and* its own secondary settling tank, and not when sewage is added stepwise to aeration units (the "step aeration process" of Gould (12)).

Two-stage activated sludge treatment has been in operation at Essen-Rellinghausen (No. 2 plant, Ruhrverband) since 1928. However, the significance of the process was not adequately recognized at the beginning, because simple means had been provided for pumping excess sludge into the influent to the primary settling tanks and digesting a thickened mixture of the two constituent sludges.

The principles of two-stage operation are outlined in Figure 1. Each stage comprises an aeration tank and a secondary settling tank. The return sludge circulates only within its own stage. However, the excess sludge is withdrawn from the second stage not for disposal but for return to the first stage. There, this sludge is put to work. It revitalizes the overloaded sludge of the first stage and is removed from the process only after its cleansing power has been exhausted. Only fully worked out first-stage sludge is removed for disposal.

Two-stage operation has the following advantages over single-stage operation:

1. The excess sludge contains less water. Accordingly, its volume is less and digestion space needs are less. Also the first-stage sludge settles well.
2. The cleansing power of all of the activated sludge is fully utilized. This makes for smaller aeration units.
3. If a by-pass around the second stage is provided, any degree of partial biological purification can be reached. Only as much first-stage effluent is admitted to the second stage as the healthy activated sludge of this stage can care for. The plant effluent is a mixture of the fully treated effluent of the second stage and the partially treated effluent of the first stage.
4. Plant operation is easily adjusted to shock overloads by disposal of partially treated sewage from the first stage.

The two-stage activated-sludge plant at Essen-Rellinghausen has been described by Sierp (3)(6). General matters relating to the two-stage process

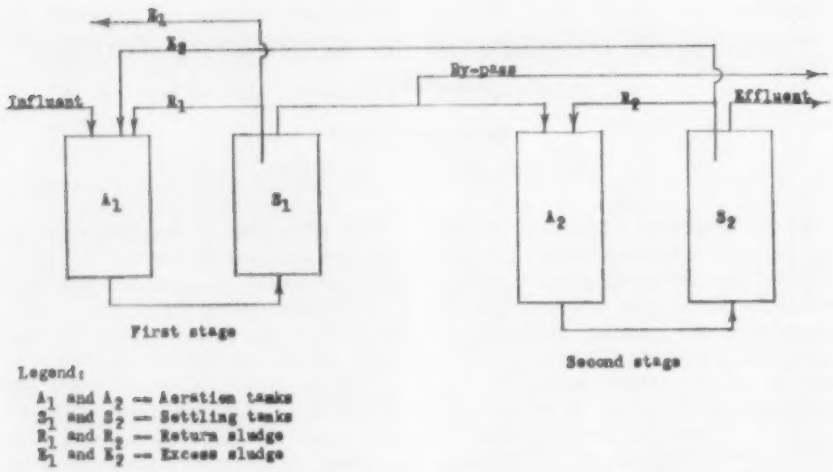


FIGURE 1.—Flow diagram for two-stage activated sludge operation.

have been discussed by Imhoff (1)(2)(4)(7) and by Imhoff and Fair (9). As reported by Mohlman and Wheeler (5), Pearse conducted two-stage experiments at the Calumet plant of Chicago from 1928 to 1930. Leiner (8) also has described the process, and Merkel (10) arranged the treatment plant at Saarbrücken for the process shortly before World War II. Scott (11) has described the two-stage operation of a small American plant, but he does not say that the excess sludge of the second stage was put to use in the aeration tanks of the first stage. The two-stage process is being operated with great success at Neersen, Kempen, and Düllken in the Niersverband by Schmitz-Lenders. In these plants, the efficiency of the first stage has been raised by the addition of iron in order to take care of the load of industrial waste waters (14).

A disadvantage of two-stage operation is the requirement of two secondary settling units, one for each stage. The settling unit of the second stage matches the conventional secondary tanks of the single-stage process in size and construction. The additional settling tank of the first stage need not be as large, because the heavily overloaded sludge of the first stage is thicker and settles more rapidly.

The primary settling tanks of conventional activated sludge plants can often be dispensed with. The two-stage process is then like Gould's high-rate activated sludge operation. All of the sewage sludge enters the first aeration tank and settles in the subsequent settling tank. In some American plants, the normally short period of pre-aeration in advance of primary sedimentation is being extended up to 30 min., and the effect of pre-aeration is being increased by the addition of return sludge. In the sense of what has been said herein, the combination of pre-aeration and primary sedimentation is then akin to the first stage in the two-stage operation of an activated sludge plant.

It looks as if two-stage operation will be employed more often in the future than it has been in the past for the treatment of the sewage of large communities. However, conversion of existing conventional treatment works to two-stage operation presents difficulties, because sewage

must be pumped from the first to the second stage and new settling tanks must be provided for the first stage.

For an existing single-stage plant, Chasik has devised simple means (at Wards Island, New York) whereby at least some of the advantages of two-stage operation have been obtained. Chasik (3) calls the resulting method of operation "activated aeration." In a 9-month experimental run, he has not altered the flow pattern of the sewage in the treatment works. However, by dividing the works into two operational groups he has changed the flow pattern of the sludge. The return sludge circulates in each group as before from the settling units that belong to the group. However, the excess sludge of the first group is not disposed of (carried to sea in tankers). Instead, the cleansing power of this sludge is first used up in the aeration tanks of the second group to which it is pumped. There, it contributes to the purification of the sewage. Only the excess sludge from the settling tanks of the second group is finally disposed of. The treatment efficiency reached lies about halfway between that of full biological treatment and that of Gould's high-rate activated sludge treatment.

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**FEDERATION HEADQUARTERS OFFICE MOVED**

By the end of April 1955, the Federation headquarters and publication office will be moved from its present location in Champaign, Ill., to new quarters in Washington, D. C. See page 513 for details.

# TRANSFORMATION AND EFFECTS OF REDUCED SULFUR COMPOUNDS IN ACTIVATED SLUDGE TREATMENT *

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Small amounts of reduced sulfur compounds may be present in domestic sewage. If sewage is allowed to become stale, there is usually an increase in the reduced sulfur compounds present. Industrial wastes may contain high concentrations of reduced sulfur compounds.

Few studies have been made to show the transformations and effects of these sulfur compounds in activated sludge treatment. Dawson and Jenkins (1) studied the effects of sulfur compounds on oxygen uptake of activated sludge by manometric methods. Heukelekian and Lassen (2) showed that organisms characteristic of activated sludge and trickling filter slime are capable of oxidizing thiosulfate, and of accelerating the oxidation of sulfide, sulfite, and bisulfite. Studies were undertaken, therefore, to determine the transformation of these compounds during aeration in the activated sludge process and the effects these compounds have upon activated sludge treatment.

## Method and Procedures

For the experiments, standard laboratory activated sludge columns containing 6 l. were used. Aeration rates were kept constant at 1 cu. ft. per gallon per 6 hr. by means of a porous diffuser connected through a calibrated manometer. Determinations on all effluents were made after 30 min. settling, with the exception of those on the initial mixed liquor, which were made after 10 min. settling to minimize any changes which might take place during settling. The inorganic sulfur compounds were separated by the method of Mangan (3); sulfate was determined by the method of Hintz and Weber (4); sulfite was determined polarographically by a method developed by Aulenbach and Balmat (5); thiosulfate and sulfide were determined iodimetrically; elemental sulfur was determined by the polarographic method of Hall (6); total sulfur was determined by the method of Smith (7); and the purification of the sewage was determined by B.O.D., suspended solids and turbidity of the effluent. Whenever reduced sulfur compounds were present in the effluents, D.O. determinations for the B.O.D. test were made by means of the polarographic method of Rand and Heukelekian (8). The determinations of all of the sulfur compounds are recorded on the basis of their sulfur content to make a comparison of the different forms of sulfur compounds easier.

## Oxidation of Reduced Sulfur Compounds in Sewage

One measure of the degree of purification of sewage by the activated sludge process is the amount of nitrate in the effluent. An effort was made to determine whether a similar increase in sulfate content takes place during the aeration of sewage with activated sludge.

Activated sludge experiments were performed using fresh domestic sewage and activated sludge from three different sources. Analyses were made for sulfide, thiosulfate, sulfite, and sulfate in the raw sewage, and the sulfate

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concentration was determined in the initial mixed liquor and in the effluent after 3, 6 and 24 hr. aeration. Sulfate production in the aeration of activated sludge without sewage addition and of sewage without activated sludge was also studied. Other variables studied were the effect of mixed liquor suspended solids concentration and the effect of staleness of activated sludge.

Reduced sulfur compounds were seldom found in the raw sewage, and when found were present in concentrations of only a few p.p.m. The sulfate concentration was not found to vary significantly during the aeration with any of the variations used. The average of 18 experiments using fresh sewage show the following results:

| Aeration Period (hr.) | Sulfate-S (p.p.m.) |
|---|---|
| 3 | 16.6 |
| 6 | 17.8 |
| 24 | 15.7 |

In another series of experiments, the sulfate concentration in the influent and in the effluent after 6 hr. aeration was determined 13 times during 35 days of continued additions of sewage in the activated sludge process. The average sulfate-sulfur concentration in the influent was 4.0 p.p.m., and in the effluent was 5.0 p.p.m.

An experiment was also performed to determine whether the sulfate concentration of stale sewage increased during aeration with activated sludge. The results showed that there is a significant increase in the sulfate concentration during aeration, as follows:

| Aeration Period (hr.) | Sulfate-S (p.p.m.) |
|---|---|
| 0 | 13.8 |
| 6 | 19.5 |
| 24 | 18.4 |

Thus it was concluded that there are insufficient amounts of reduced sulfur compounds present in fresh sewage to cause any significant increase in the sulfate concentration of the effluent after aeration. However, with stale sewage, where the sulfur compounds may be in a reduced state, there is an increase in the sulfate concentration during aeration.

### Transformation and Effects of Added Sulfite

Studies were made to determine the transformation and effects of added sulfite in the activated sludge process. Sodium sulfite was added in concentrations of 50 and 500 p.p.m. as sulfur to separate activated sludge columns and aerated. The results were compared to a control containing no added sulfite. Determinations were made for sulfide, thiosulfate, sulfite and sulfate in the effluent after various periods of aeration. The degree of purification with these same periods of aeration was also determined.

The results of the experiment are summarized in Table I. At no time during the aeration were sulfide and thiosulfate found. The sulfite added disappeared slowly, with some remaining in the effluent after 6 hr. aeration with the addition of both 50 and 500 p.p.m. After 24 hr. aeration the sulfite disappeared completely with both additions. The sulfate recovery lagged behind the disappearance of the sulfite. With the addition of 50 p.p.m. sulfite sulfur, all the added sulfur was recovered as sulfate within 24 hr., but with the addition of 500 p.p.m. not all the added sulfur was recovered as sulfate. This indicates that there is some intermediate compound formed in the oxidation of sulfite to sulfate. It is not known what this compound may be, but it is possible that it is the result of the biological oxidation of the sulfite. The addition of 50 p.p.m. had little effect upon the purification of the sewage as shown by the B.O.D. and the suspended solids in the effluents as compared with the control. With the addition of 500 p.p.m., the B.O.D. in the effluent after 6 hr. aeration was higher than in the control, probably

due to the unoxidized sulfite remaining in the effluent, which continued to exert an oxygen demand. After 24 hr. aeration the B.O.D. was similar to that of the control.

The transformations of the added sulfite are shown in Figure 1. The aeration time is plotted on a log scale merely to expand the first part of the aeration, during which time determinations were made more often. The disappearance of the sulfite followed a rather straight line with the addition of 500 p.p.m., but lack of sufficient data prevents the confirmation of this with the addition of 50 p.p.m. No particular significance is attached to the straight-line logarithmic disappearance of the sulfite. The recovery of sulfate shows a lag after the disappearance of the sulfite. All the added sulfite was recovered after 24 hr. aeration with the addition of 50 p.p.m., but not all was recovered with the addition of 500 p.p.m. From the slope of the line indicating the recovery of sulfate with the addition of 500 p.p.m. sulfite, it appears that the amount of sulfite oxidized to sulfate is a function of the amount and time of aeration, and that the sludge used was not capable of oxidizing more than about 300 p.p.m. sulfite to sulfate within 24 hr. aeration.

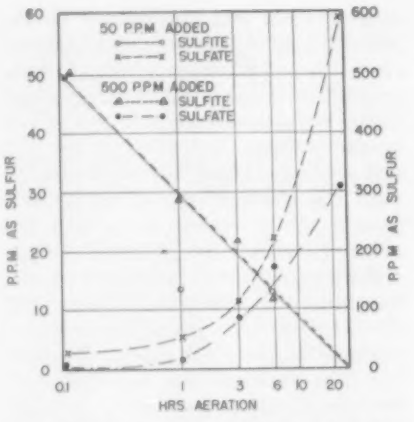



**FIGURE 1.—Sulfur transformations during activated sludge treatment with 50- and 500-p.p.m. additions of sulfite (as S) to sewage.**

**TABLE I.—Transformation and Effect of Sulfite in the Activated Sludge Process**

| Determination | Aeration Period (hr.) | Sulfite-S Added (p.p.m.) | | |
|---|---|---|---|---|
| | | 0[1] | 50 | 500 |
| Sulfite (p.p.m. S) | —[2] | 0 | 0 | 0 |
| | 0 | — | 49.8 | — |
| | 1 | 0 | 14.7 | 284 |
| | 3 | 0 | — | 216 |
| | 6 | 0 | 13 | 116 |
| | 24 | 0 | 0 | 0 |
| Sulfate (p.p.m. S) | —[2] | 6.2 | 6.2 | 6.2 |
| | 0 | — | 3.2 | 4.3 |
| | 1 | 8.8 | 4.9 | 12.1 |
| | 3 | 8.8 | 11.1 | 83.8 |
| | 6 | 4.9 | 20.9 | 162 |
| | 24 | 8.8 | 59.3 | 310 |
| B.O.D. (p.p.m.) | —[2] | 84 | 84 | 84 |
| | 6 | 63 | 58 | 177 |
| | 24 | 19.8 | 29.4 | 26.7 |
| Susp. solids (p.p.m.) | —[2] | 66 | 66 | 66 |
| | 6 | 38 | 36 | 54 |
| | 24 | 14 | 19 | 29 |

[1] Control.
[2] Raw sewage.

Determination of the total sulfur in the sludge showed that there is a small amount of sulfur absorbed in the sludge with the addition of 500 p.p.m. sulfite. This amount of increased sulfur in the sludge accounted for only a few p.p.m. sulfur in the aeration system, and it cannot make up for the 200 p.p.m. sulfur which was not accounted for as either sulfite or sulfate.

An increase in the sludge oxygen demand with the 500 p.p.m. sulfite addition was also noted, which might be attributed to the oxidation to sulfate of some intermediate compound formed. This further indicates that the lag between the disappearance of the sulfite and the recovery of the sulfate is the result of the biological oxidation of the sulfite.

An experiment was performed with continued batch additions of 0, 10, 100 and 1,000 p.p.m. sulfite sulfur to determine the effects of repeated sulfite additions on purification by the activated sludge process. Sewage and sulfite additions and effluent removals were made three times daily, and determinations were made on the effluents after exactly 7 hr. aeration once a day. Two additions of sewage without the sulfite were made before the first sulfite additions, to acclimatize the sludge to the sewage to be used in the experiment.

The effects of the sulfite on the B.O.D. in the effluent are shown in Figure 2. Addition of 10 p.p.m. had no significant effect on the B.O.D., but addition of 100 p.p.m. resulted in an effluent B.O.D. 10 to 20 p.p.m. greater than that of the control. With the addition of 1,000 p.p.m. sulfite (not shown in Figure 2), the B.O.D. of the effluent was always greater than that of the sewage influent, indicating the continued oxidation of sulfite remaining in the effluent after aeration. After 7 days operation there appeared to be no significant increase in the ability of the sludge to purify the sewage with the addition of 100 p.p.m. sulfite.

Suspended solids and turbidities of the effluents were similar to the B.O.D. Addition of 10 p.p.m. sulfite had no effect, and the presence of 100 p.p.m. resulted in lower reduction. Addition of 1,000 p.p.m. caused an increase in the suspended solids and no reduction in the turbidity, and the sludge appeared to break up.

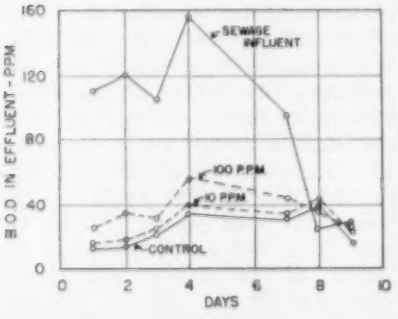



FIGURE 2.—Effect of repeated sulfite additions to sewage on B.O.D. removals by activated sludge treatment.

The greater the amount of sulfite added, the less was the nitrate content of the effluent. Small amounts of nitrates were found with the addition of 1,000 p.p.m. sulfite. There was no significant change in the pH with the additions of sulfite; addition of 1,000 p.p.m. increased the pH to a maximum value of 8.2. The sludge index with the 1,000-p.p.m. addition was higher than with the other additions, indicating poorer sludge. Within 7 days operation, about one-half of the sludge was lost with the addition of 1,000 p.p.m. sulfite, whereas there was no loss of sludge with lower sulfite additions. This shows that the sludge was broken up by the high sulfite addition.

Lower sulfite additions had no effect on the sludge oxygen demand, but the addition of 1,000 p.p.m. caused an increased sludge oxygen demand, indicating that greater amounts of air are required to oxidize the sulfite remaining in the effluent. On the final day of the experiment, determination of the sulfite remaining in the effluent showed 632 p.p.m. in the column containing 1,000 p.p.m. added sulfite, and none in the other columns. Thus, up to at least 100 p.p.m. sulfite can be removed by aeration within 7 hr. and more than 350 p.p.m. out of an added 1,000 p.p.m. can be removed. This is somewhat better than when only a single addition was made, which showed that a small amount of sulfite remained after 6 hr. aeration with the addition of only 50 p.p.m. Although the experiment does not show any acclimatization to purification in the presence of sulfite, it does indicate that there may be some improvement in the removal of sulfite by continuous additions of sulfite.

A similar experiment was set up to determine if there is any acclimatization of activated sludge to oxidize sulfite and to purify sewage in the presence of sulfite. Initially 100 p.p.m. sulfite sulfur was added, but this was increased when it became evident that there was acclimatization to this concentration. Sewage additions were made three times a day, and analyses were made at least twice a week for the sulfur compounds present and for the indices of purification after 6 hr. aeration. Two additions of sewage were made before the first addition of sulfite in order to acclimatize the sludge to the sewage being used.

The percentage of recovery of the added sulfite as both sulfite and sulfate is shown in Figure 3. Sulfide and thiosulfate were found to be absent at all times. For the first two weeks, with the addition of 100 p.p.m. sulfite, a small amount of sulfite remained in the effluent. Thereafter the sludge apparently was capable of oxidizing all the added sulfite to sulfate within 6 hr. aeration; no sulfite was found in the effluent when the dosage was increased to 250 p.p.m. This shows definite acclimatization to the oxidation of sulfite, since with single additions, sulfite remained after 6 hr. aeration with the addition of only 50 p.p.m. sulfite. Small amounts of sulfite were found in the effluent when the dosage was increased to 500 p.p.m. Higher amounts were found in the effluent with 750- and 1,000-p.p.m. additions. The percentage of recovery as sulfate correspondingly decreased with these higher dosages. However, continuing the aeration with the final addition of 1,000 p.p.m. up to 24 hr. resulted in the oxidation of all the added sulfite to sulfate. This indicates that the oxidation of sulfite in the activated sludge process is a function of the time of contact, in addition to acclimatization.

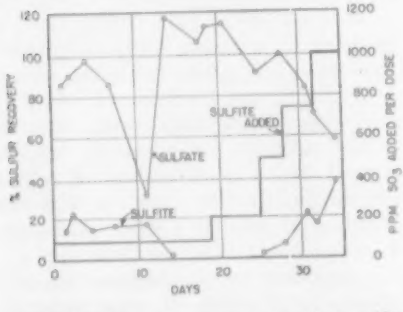



FIGURE 3.—Recovery of added sulfite after 6 hr. aeration of activated sludge-sewage mixture with repeated daily additions.

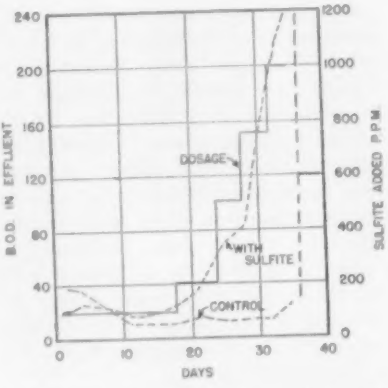



FIGURE 4.—Effect of repeated sulfite additions to sewage on the B.O.D. of the effluent by activated sludge treatment.

The effects of the added sulfite on the purification of the sewage are best shown by the B.O.D. of the effluent after 6 hr. aeration (Figure 4). With the first addition of sulfite, the B.O.D. of the effluent was rather high, but with continued additions of this concentration, the B.O.D. of the effluent approached that of the control. With the addition of 200 p.p.m. there was an increase in the B.O.D., and with the addition of 500 p.p.m. the increase was even greater. With the addition of 750 and 1,000 p.p.m. the B.O.D. of the effluent was greater than that of the influent, probably due to the continued oxidation of the sulfite that remained after 6 hr. aeration. However, continuing the aera-

tion after the last addition of 1,000 p.p.m. sulfite for 24 hr. resulted in a B.O.D. of the effluent the same as that in the control. This shows that after the oxygen requirement for the oxidation of the sulfite is met, the purification of the sewage proceeds normally.

The suspended solids and turbidity removal with the additions of sulfite follow closely the results of the B.O.D. With repeated additions of 100 p.p.m., there was a gradual increase in the suspended solids and turbidity removal. The removals decreased with the additions of greater amounts of sulfite, the addition of 500 p.p.m. and more sulfite resulting in an increase in the suspended solids in the effluent to values greater than in the sewage used. However, continuing the aeration with the last addition of 1,000 p.p.m. sulfite for 24 hr. resulted in suspended solids and turbidity removal similar to that of the control.

With addition of less than 500 p.p.m., the sludge index was at least as good as the control, but with addition of 500 p.p.m. and greater, the sludge index became poorer than that of the control. Up to 750 p.p.m., addition of sulfite resulted in less build-up in solids than the control. With addition of 1,000 p.p.m., however, the sludge began to break up and solids were lost. This appears to be the result of oxygen starvation caused by the large oxygen demand of the sulfite.

The results show that activated sludge can be acclimatized to oxidize up to 500 p.p.m. sulfite to sulfate within 6 hr. aeration and up to at least 1,000 p.p.m. within 24 hr. aeration. Satisfactory purification may be achieved with 6 hr. aeration with 200 p.p.m. sulfite, and there is acclimatization to purify sewage up to at least 1,000 p.p.m. sulfite within 24 hr. aeration. The oxidation of sulfite is dependent upon the amount of oxygen supplied and the contact time. The sulfite is not toxic to the organisms responsible for the purification of sewage in the activated sludge process.

## Transformation and Effects of Added Sulfide

Studies were made to determine the transformation and effects of added sulfide in the activated sludge process. Sodium sulfide was added in concentrations of 10 and 100 p.p.m. as sulfur to separate activated sludge columns. The results (Table II) were compared with a control containing no added sulfide. Determinations were made for sulfide, elemental sulfur, thiosulfate, sulfite and sulfate in the effluent after various periods of aeration. The degree of purification with these same periods of aeration was also determined.

Sulfite was absent at all times, and there was no significant change in the sulfate concentration throughout the experiment. The added sulfide rapidly disappeared, only a small amount remaining after 1 hr. aeration with the 100-p.p.m. addition. There was a rapid increase in the elemental sulfur concentration to a value that remained constant from the third to the

**TABLE II.—Transformation and Effects of Sulfide in the Activated Sludge Process**

| Determination | Aeration Period (hr.) | Sulfide-S Added (p.p.m.) | | |
|---|---|---|---|---|
| | | 0[1] | 10 | 100 |
| Sulfide (p.p.m. S) | —[2] | 1.2 | 1.2 | 1.2 |
| | 0 | 1.7 | 1.7 | 40.7 |
| | 1 | 0 | 0 | 4.5 |
| | 3 | 0 | 0 | 0 |
| | 6 | 0 | 0 | 0 |
| | 24 | 0 | 0 | 0 |
| Elemental sulfur (p.p.m. S) | —[2] | — | — | — |
| | 0 | — | — | — |
| | 1 | — | — | — |
| | 3 | 0 | 3.2 | 23.6 |
| | 6 | 0 | 2.2 | 23.8 |
| | 24 | 0 | 6.6 | 0.8 |
| Thiosulfate (p.p.m. S) | —[2] | 10.2 | 10.2 | 10.2 |
| | 0 | 12.6 | 10.2 | 0 |
| | 1 | 20.2 | 42.2 | 52.3 |
| | 3 | 26.9 | 28.8 | 78.8 |
| | 6 | 18.1 | 22.8 | 76.0 |
| | 24 | 24.1 | 14.9 | 61.8 |
| B.O.D. (p.p.m.) | —[2] | 345 | 345 | 345 |
| | 6 | 27 | 51 | 350 |
| | 24 | 13 | 11 | 137 |
| Susp. solids (p.p.m.) | —[2] | 92 | 92 | 92 |
| | 1 | 68 | 90 | 115 |
| | 6 | 25 | 41 | 103 |
| | 24 | 5 | 7 | 25 |

[1] Control.
[2] Raw sewage.

sixth hours of aeration, after which it dropped to almost none. The thiosulfate concentration showed a similar trend, although there was more thiosulfate formed, and the final value after 24 hr. aeration showed considerable thiosulfate remaining. The addition of 10 p.p.m. sulfide did not provide significant sulfur to follow the transformations accurately, but the addition of 100 p.p.m. readily shows the transformations. The addition of 10 p.p.m. resulted in less purification than the control after aeration for 6 hr. or less. With the addition of 100 p.p.m. there was no purification at all during the first 6 hr.

The sulfur transformations with the addition of 100 p.p.m. sulfide are shown in Figure 5. The aeration time is plotted on a logarithmic scale merely to expand the early part of the experiment. The sulfide disappeared almost entirely within the first hour. The thiosulfate and elemental sulfur appeared within the first hour, remained fairly constant during the third and sixth hours, and then decreased. The thiosulfate concentration was greater than the elemental sulfur concentration. From these results it is not clear whether the sulfide is oxidized entirely to elemental sulfur, which is in turn oxidized to thiosulfate, or whether some of the sulfide is oxidized directly to thiosulfate. Possibly the oxidation to elemental sulfur is a chemical oxidation, and to thiosulfate is biological. However, it does appear that the elemental sulfur is oxidized to thiosulfate, since the elemental sulfur disappears before the thiosulfate. After aeration for 24 hr., there was a reduction in the elemental sulfur and the thiosulfate, but there was no increase in any other sulfur compound for which determinations were made. It is possible that the thiosulfate was oxidized to some intermediate compound, such as tetrathionate, which was not determined.

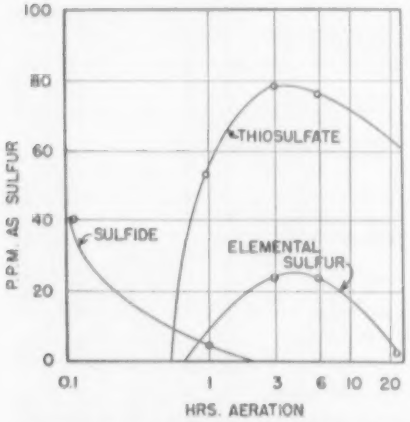



**FIGURE 5.—Sulfur transformations during activated sludge treatment with the addition of 100 p.p.m. of sulfide (as S).**

The turbidity of the effluent after 6 hr. aeration with the addition of 100 p.p.m. sulfide was greatly increased due to the presence of the elemental sulfur. The sludge oxygen demands with the addition of both 10 and 100 p.p.m. sulfide were identical, but it was lower than that of the control, indicating some interference with the activity of the organisms present in the activated sludge.

An experiment was performed with repeated batch additions of 0, 10, 25, 50, 100 and 500 p.p.m. sulfide to determine the effects of the constant additions upon purification by the activated sludge process. Sewage and sulfide additions and effluent removals were made three times a day, and determinations were made in the effluents after exactly 6 hr. aeration once a day. Two additions of sewage without the sulfide were made before the first additions of sulfide to acclimatize the sludge to the sewage to be used in the experiment.

The effects of the added sulfide are shown in Figure 6. It may be seen that except for the first day, the B.O.D. of the effluent with the addition of 10 p.p.m. sulfide was better than that of the control. With the

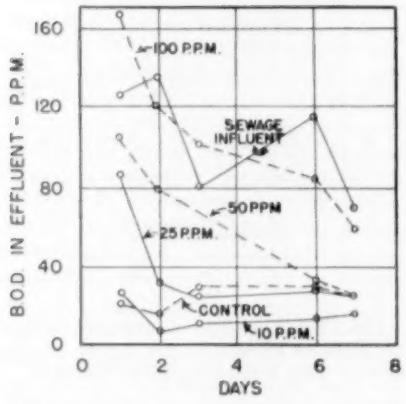



**FIGURE 6.—Effect of repeated additions of various concentrations of sulfide to sewage on the B.O.D. of the effluent obtained by activated sludge treatment.**

addition of 25 and 50 p.p.m. sulfide, there was poor purification initially, but by the third and sixth days for the respective sulfide additions, the effluents were the same as the control. The addition of 100 p.p.m. sulfide resulted in little or no B.O.D. removal, and the addition of 500 p.p.m. resulted in a B.O.D. of the effluent considerably higher than that of the raw sewage.

The suspended solids in the effluent was similar to the B.O.D. The suspended solids in the raw sewage was rather low. This resulted in the loss of solids initially with the addition of 25 and 50 p.p.m. sulfide, and it was continuous with the addition of 100 and 500 p.p.m.

The turbidities of the effluents were similar to the B.O.D. and suspended solids. The addition of 100 p.p.m. or more sulfide resulted in an increase in the turbidity over the raw sewage.

The high suspended solids and turbidities in the effluents correspond with a reduction in the suspended solids in the mixed liquor, indicating that the addition of 100 p.p.m. or more sulfide caused the sludge to break up. Throughout the experiment the sludge index improved with all of the sulfide additions, but the improvement was less the greater the sulfide addition.

The greater the sulfide additions, the less nitrate appeared in the effluents.

Sulfite, thiosulfate, and sulfide in the effluents were determined (Table III). None of these reduced sulfur compounds were found in the control and with the addition of 10 p.p.m. sulfide. With the addition of 25 p.p.m., thiosulfate was found in the effluent the first two days, but none was found thereafter, and with the addition of 50 p.p.m., thiosulfate was found for the first 3 days. The addition of 100 p.p.m. sulfide resulted in small amounts of sulfide remaining in the effluent for the first 3 days, and thiosulfate was also found the first 3 days. With the addition of 500 p.p.m. sulfide, about 300 p.p.m. sulfide was found in the effluent throughout

**TABLE III.—Reduced Sulfur Compounds After 6 Hr. Aeration with Various Sulfide Additions**

| Number of S Adds. | Days | Reduced Compounds (as p.p.m. S)[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 25 p.p.m. S | 50 p.p.m. S | 100 p.p.m. S | | | 500 p.p.m. S | | |
| | | $S_2O_3$ | $S_2O_3$ | Sulfide | $SO_3$ | $S_2O_3$ | Sulfide | $SO_3$ | $S_2O_3$ |
| 1 | 1 | 53.2 | 26.6 | 1.25 | 0 | 53.2 | 0 | 0 | 19.1 |
| 4 | 2 | 40.1 | 30.1 | 1.40 | 2.5 | 51.7 | 114 | 0 | 322 |
| 7 | 3 | 0 | 35.8 | 1.60 | 1.6 | 86.2 | 268 | 0 | 225 |
| 16 | 6 | 0 | 0 | 0 | 0 | 0 | 320 | 9.8 | 165 |
| 19 | 7 | 0 | 0 | 0 | 0 | 0 | 307 | 23.0 | 157 |

[1] Determinations for all reduced sulfur compounds were made on all samples. Where no figures appear in the table, reduced sulfur compounds were never found to be present.

the experiment. On the sixth and seventh days, 10 and 23 p.p.m. sulfite were found, respectively, in the effluents, and the thiosulfate concentration in the effluent gradually decreased from 322 p.p.m. on the second day to 157 p.p.m. on the seventh day. This shows that up to 100 p.p.m. sulfide there is an increasing ability of the activated sludge to oxidize the added sulfide, but that the addition of 500 p.p.m. sulfide results in a decreasing ability of the sludge to oxidize the sulfide.

A similar experiment was set up to determine if there is any acclimatization of activated sludge to oxidize sulfide and to purify sewage in the presence of sulfide. Initially, 25 p.p.m. sulfide was added, but this was increased when it became evident that there was acclimatization to this concentration. Sewage additions were made three times a day, and analyses were made for the sulfur compounds present and for the indices of purification after 6 hr. aeration at least twice a week. Two additions of sewage were made before the first addition of sulfide in order to acclimatize the sludge to the sewage being used.

The oxidation of the sulfide to sulfate is shown in Figure 7 as the percentage of recovery as sulfate of the added sulfide. During the first 6 days, with the addition of 25 p.p.m. sulfide, there was little conversion to sulfate. On the seventh day, with acclimatization and an increase in the sulfide added, all the added sulfide was recovered as sulfate after 6 hr. aeration. This shows that activated sludge can be acclimatized to oxidize at least 100 p.p.m. sulfide completely to sulfate within 6 hr. aeration.

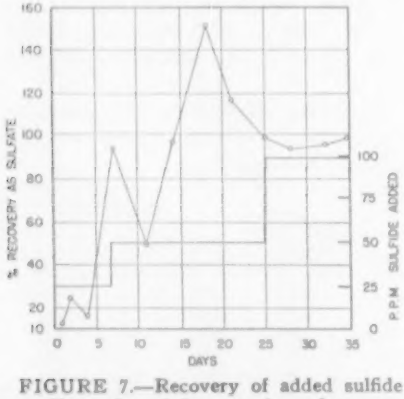



FIGURE 7.—Recovery of added sulfide as sulfate after 6 hr. aeration of sewage with activated sludge with repeated additions.

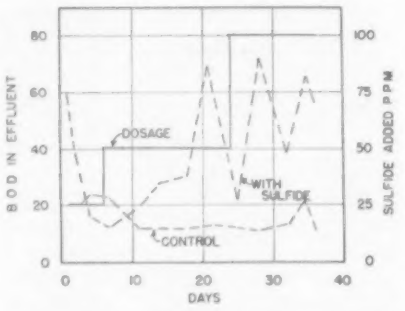



FIGURE 8.—Effect of repeated sulfide additions to sewage on the B.O.D. of the effluent from activated sludge treatment.

The effects of the added sulfide upon the purification of the sewage are best shown by the B.O.D. of the effluent after 6 hr. aeration (Figure 8). For the first two days, there was an increase in the B.O.D. as compared with that of the control. By the fourth day, the B.O.D. was less than that of the control, and it was for this reason that the sulfide dosage was increased to 50 p.p.m. on the seventh day. It resulted in a gradual increase in the B.O.D. of the effluent up to 70 p.p.m. It then decreased to about 20 p.p.m., but upon the addition of 100 p.p.m. sulfide the B.O.D. again increased considerably.

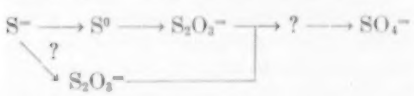
The suspended solids and turbidity of the effluents are very similar to the B.O.D., thereby confirming the effects of the sulfide upon purification as measured by the B.O.D.

The sludge index with the sulfide additions was as good as, or better than, that of the control at all times.

However, confirming the high concentrations of suspended solids and turbidity in the effluents, the sludge volume decreased markedly with the addition of 50 and 100 p.p.m. sulfide. The lack of purification can be correlated to the loss of solids in the sludge. Thus it appears that concentrations of 50 p.p.m. and greater of sulfides cannot be tolerated for periods exceeding about one week because the sulfide causes the sludge to break up, with the resulting loss of purification.

Aeration for 24 hr. after the final sulfide addition revealed no additional purification as compared with the 6 hr. aeration. This was expected, due to the low sludge concentration.

The results of the experiments with the addition of sulfide show that the oxidation of sulfide in the activated sludge process proceeds as follows:




The intermediate or intermediates between thiosulfate and sulfate was not determined, but Gleen and Quastel (9) and Vishniac (10) indicate that tetrathionate is an intermediate in the oxidation of thiosulfate to sulfate. Sulfite was not found to be an intermediate as was found in the chemical oxidation of sulfide by Postnikov *et al.* (11). Elemental sulfur was found during the process, and there was a significant increase in the thiosulfate content. Thiosulfate remains after the disappearance of the elemental sulfur, indicating that the elemental sulfur is oxidized to thiosulfate. Since both elemental sulfur and thiosulfate were found to be present at the same time during the early part of the aeration, it is not clear whether all the thiosulfate present is the result of the oxidation of the elemental sulfur, or whether some thiosulfate is produced directly from the sulfide. It is very likely that the production of elemental sulfur is the result of the chemical oxidation of the sulfide, and the production of thiosulfate is the result of the biological oxidation of the sulfide and the elemental sulfur.

Activated sludge may need acclimatization to oxidize even 25 p.p.m. sulfide to sulfate within 6 hr. aeration. However, after acclimatization at least 100 p.p.m. sulfide may be completely oxidized to sulfate within 6 hr. aeration.

Activated sludge may be acclimatized to purify sewage containing up to 50 p.p.m. sulfide. However, this concentration of sulfide causes the sludge to break up, with the subsequent loss of ability to purify sewage after about a week. The presence of 100 p.p.m. sulfide causes the sludge to break up more rapidly. Therefore, sewage containing 25 p.p.m. sulfide may be treated by the activated sludge process, and sewage containing up to 50 p.p.m. may be treated if it is present for periods not exceeding about one week.

### Transformation and Effects of Added Thiosulfate

Little information is available concerning the transformation and effects of thiosulfate in the activated sludge process. This may be due to the fact that thiosulfate is seldom present in sewage or industrial wastes. However, it has been shown that the treatment of sulfide results in the formation of thiosulfate. Studies were made to determine the transformations and effects of added thiosulfate in the activated sludge process.

To determine the transformation of the thiosulfate, it was added as the sodium salt to separate activated sludge columns in concentrations of 100, 500 and 1,000 p.p.m. as sulfur. The results were compared with a control containing no added thiosulfate. Determinations were made for sulfide, thiosulfate, sulfite, and sulfate in the raw sewage and in the effluents after various periods of aeration. The de-

TABLE IV.—Transformation and Effects of Thiosulfate in the Activated Sludge Process

| Determination | Aeration Period (hr.) | Thiosulfate—S Added (p.p.m.) | | | |
|---|---|---|---|---|---|
| | | 0[1] | 100 | 500 | 1,000 |
| Thiosulfate (p.p.m. S) | Raw sewage | 8.9 | 8.9 | 8.9 | 8.9 |
| | 0 | 6.3 | 86.5 | 372 | — |
| | 1 | 13.6 | 99.2 | 406 | 884 |
| | 3 | 20.3 | 79.5 | 420 | 714 |
| | 6 | 6.5 | 94.1 | 444 | 1,028 |
| | 24 | 13.3 | 32.0 | 358 | 753 |
| B.O.D. (p.p.m.) | Raw sewage | 273 | 273 | 273 | 273 |
| | 6 | 16 | 65 | 58 | 29 |
| Susp. solids (p.p.m.) | Raw sewage | 129 | 129 | 129 | 129 |
| | 6 | 3 | 4 | 29 | 16 |
| | 24 | 0 | 0 | 0 | 5 |
| Total S in sludge[2] | Initial sludge | 0.220 | 0.220 | 0.220 | 0.220 |
| | 24 | 0.185 | 0.187 | 0.962 | 2.33 |

[1] Control.
[2] As per cent S in suspended solids.

gree of purification with these same periods of aeration was also determined.

The results are summarized in Table IV. Sulfide and sulfite were found to be absent at all times, and there was no significant change in the sulfate concentration in the effluents at any time; therefore these compounds are not recorded in the table. It may be seen that there was no disappearance of the thiosulfate within 6 hr. aeration, and the disappearance after 24 hr. aeration is only slight. It appears that the sludge used was not capable of oxidizing thiosulfate. There was a marked decrease in the B.O.D. reduction with the addition of 100 and 500 p.p.m. thiosulfate sulfur, but there was less effect with the addition of 1,000 p.p.m. It must be noted that the B.O.D. was determined on the effluents which contained almost all of the added thiosulfate. Since the B.O.D. was not considerably increased even after 5 days incubation, this further indicates that there is a lack of organisms capable of oxidizing thiosulfate. The suspended solids in the effluent after 6 hr. aeration were highest with the 500-p.p.m. addition, and were somewhat higher than the control with the 1,000-p.p.m. addition. There was no significant difference in the suspended solids after 24 hr. aeration. There was a marked increase in the total sulfur content of the sludge with the addition of 500 and 1,000 p.p.m. thiosulfate sulfur, indicating that some sulfur was absorbed by the sludge. However, the amount of sulfur absorbed in the sludge was not sufficient to make up for the amount of thiosulfate that disappeared within 24 hr. aeration. Since there was also no increase in the sulfate concentration of the effluent, this indicates that the thiosulfate is oxidized to some intermediate compound for which determinations were not made.

To determine whether or not there was any acclimatization of the sludge to oxidize thiosulfate, an experiment was performed with repeated batch additions of sewage containing thiosulfate. Since the previous experiment showed that thiosulfate had no effects upon purification in concentrations up to 1,000 p.p.m. as sulfur, 1,000 p.p.m. thiosulfate sulfur was chosen as the constant concentration

to be added. Sewage additions were made three times a day, and analyses were made for the sulfur compounds present and for the indices of purification after 6 hr. aeration at least twice a week. Two additions of sewage were made before the first addition of thiosulfate in order to acclimatize the sludge to the sewage being used.

Of the sulfur compounds regularly determined, thiosulfate and sulfate were the only ones which showed significant changes. A determination for elemental sulfur on the 14th day showed a total of 23.5 p.p.m. The transformation of thiosulfate to sulfate and the effect of thiosulfate addition on the B.O.D. of the effluent are given in Table V. There was a gradual reduction in thiosulfate concentration of the effluent to a low of 254 p.p.m. on the 52nd addition. After this time the thiosulfate concentration in the effluent increased slowly. The sulfate concentration in the effluent showed exactly the opposite trend. For the first two days, there was no increase in the sulfate concentration, but some acclimatization to the oxidation of the thiosulfate to sulfate occurred starting with the fourth day. The maximum sulfate recovered was 24 per cent on the 52nd addition. After this time the sulfate decreased somewhat. After aerating the final sewage addition for 24 hr., the sulfate concentration reached 334 p.p.m., and the thiosulfate concentration was decreased to 481 p.p.m.

It will be noticed that the percentage of recovery of sulfate and thiosulfate does not account for all the sulfur in the thiosulfate added. This indicates, as with the experiment containing added sulfide, that the thiosulfate is oxidized to some intermediate, for which determinations were not made, in the course of its oxidation to sulfate. It is assumed that tetrathionate is at least one of these intermediates.

The B.O.D. of the effluent was always greater than that of the influent. This is most likely due to the continued oxidation of the thiosulfate remaining in the effluent during the B.O.D. determination. All D.O. determinations for the B.O.D. test were made by means of the polarograph in

**TABLE V.—Sulfur Transformations and the Effect of Repeated Addition of 1,000 p.p.m. Thiosulfate[1] on the Purification of Sewage by the Activated Sludge Process[2]**

| No. of Additions | Sulfate (p.p.m.) | | Thiosulfate (p.p.m.) | | B.O.D. (p.p.m.) | |
|---|---|---|---|---|---|---|
| | Infl.[3] | Effl. | Infl.[3] | Effl. | Infl.[3] | Effl. |
| 1 | 6.9 | 5.5 | 6.2 | 831 | 21 | — |
| 4 | 4.1 | 5.5 | 0 | 677 | 21 | — |
| 10 | 3.6 | 44.0 | 15.1 | 668 | 26 | 426 |
| 19 | 5.5 | 108 | 15.9 | 640 | 24 | 228 |
| 31 | 7.1 | 127 | 23.3 | 490 | 11 | 630 |
| 40 | 3.0 | 201 | 16.6 | 483 | 13 | 675 |
| 52 | 3.C | 241 | 18.4 | 254 | 12 | 510 |
| 61 | 3.6 | 174 | 18.4 | 550 | 15 | 810 |
| 73 | 2.7 | 141 | 13.6 | 362 | 13 | 780 |
| 82 | 10.2 | 55 | 3.8 | 541 | 13 | 930 |
| 94 | 2.2 | 146 | 28.2 | 668 | 13 | 764 |
| 103 | 0 | 113 | 32.4 | 772 | 24 | 810 |
| 103[4] | 0 | 334 | 32.4 | 481 | 13 | 720 |

[1] As S.
[2] After 6 hr. aeration in the supernatant after settling.
[3] Raw sewage.
[4] After 24 hr. aeration in the supernatant after settling.

order to eliminate the effect of any thiosulfate remaining. It may be seen that as the sludge became acclimatized to the thiosulfate, the B.O.D. increased. This indicates that there was an increase in the number of organisms capable of oxidizing the thiosulfate remaining in the effluent. The slightly lower value on the 52nd addition corresponds to the maximum reduction in the thiosulfate during the aeration.

The suspended solids in the effluent were not at all similar to the B.O.D. After initial high values, there was little increase in suspended solids as compared to the control.

The turbidity varied even less than the suspended solids as compared to the control. This indicates that purification occurred, and that the increase in the B.O.D. was due to the thiosulfate remaining in the effluent.

The sludge index with the thiosulfate additions was poorer than that of the control. However, there was a continued increase in the suspended solids concentration throughout the experiment, although it was not quite as great as in the control. On the fourth day of operation, the sludge became very granular, and by the eleventh day it was noted to be pale with white particles present. Since there was a large increase in the total sulfur in the sludge at the end of the experiment, it is considered that this accumulation of sulfur caused the whitening of the sludge. It may have been the result of absorption of elemental sulfur, as this was found to be present during the experiment.

The presence of elemental sulfur appears to be a reduction of the thiosulfate. However, Gleen and Quastel (9) and Vishniac (10) have shown that elemental sulfur may be formed in the aerobic oxidation of thiosulfate in the presence of excess thiosulfate. It is possible that this elemental sulfur is incorporated in the sludge. This would also provide a reason for the decreasing ability of the sludge to oxidize the thiosulfate after the 52nd addition. If the active organisms in the sludge were being replaced by elemental sulfur, there would be less ability of the sludge to oxidize thiosulfate.

Activated sludge may, therefore, be acclimatized to oxidize up to 250 p.p.m. thiosulfate completely to sulfate within 6 hr. aeration. At the same time, a total of 750 p.p.m. thiosulfate may be removed from solution. The difference between the amount of thiosulfate removed and that recovered as sulfate is considered to be partly an intermediate such as tetrathionate, formed in the oxidation of the thiosulfate to sulfate, and partly to the formation of elemental sulfur that accumulates in the sludge.

## Summary

A series of activated sludge experiments was performed to determine the transformations and effects of various reduced sulfur compounds in sewage to be treated by that process. Single batch additions were made with analyses at several intervals to determine the transformation of the sulfur compounds during the treatment and to determine the immediate effects of those compounds. Continuous batch additions were made to determine the long-time effects of the presence of these sulfur compounds and to determine if there is any acclimatization of the sludge to oxidize the sulfur compound added and to purify the sewage in the presence of the added sulfur compound.

## Conclusions

1. The amount of reduced sulfur compounds present in the sewage used was not of sufficient magnitude to be measured by the increase in sulfate concentration during aeration in the activated sludge process.

2. Sulfite is oxidized to some intermediate before it is completely oxi-

dized to sulfate. This intermediate is not known, but it is considered to be the result of the biological oxidation of the sulfite.

3. Activated sludge may be acclimatized to oxidize up to 500 p.p.m. sulfite sulfur to sulfate within 6 hr. aeration and up to at least 1,000 p.p.m. within 24 hr.

4. The oxidation of sulfite in the activated sludge process is dependent upon the quantity of air supplied, acclimatization, and the time of contact.

5. Sulfite is not toxic to activated sludge, it merely requires large amounts of oxygen. After the sulfite is completely oxidized, purification follows when up to 1,000 p.p.m. sulfite has been added.

6. In the activated sludge process it is not clear whether all the sulfide is first oxidized to elemental sulfur and then to thiosulfate, or whether some of the sulfide is oxidized directly to thiosulfate. The formation of elemental sulfur may be a chemical oxidation, and the direct formation of thiosulfate from sulfide may be a biological oxidation. There is an intermediate in the complete oxidation of the thiosulfate to sulfate. The intermediate compounds and their number are not known, but the literature indicates that tetrathionate is one of them.

7. Activated sludge can be acclimatized to oxidize at least 100 p.p.m. sulfide completely to sulfate within 6 hr. aeration. The organisms that must be increased are those responsible for the oxidation of the elemental sulfur, thiosulfate, and the intermediates.

8. Activated sludge may be acclimatized to purify sewage containing 25 p.p.m. sulfide, and 50 p.p.m. can be tolerated for periods of about one week. Longer periods of addition of 50 p.p.m. and the addition of 100 p.p.m. sulfide resulted in breaking up of the sludge, with a subsequent loss of purification.

9. Sulfide reduces the activity of activated sludge.

10. The addition of thiosulfate to sewage to be treated by the activated sludge process confirms the oxidation of thiosulfate to sulfate with the production of one or more intermediates.

11. Activated sludge may be acclimatized to remove up to 750 p.p.m. thiosulfate sulfur from solution within 6 hr. aeration, of which up to 250 p.p.m. may be oxidized completely to sulfate.

12. Elemental sulfur is formed by the addition of 1,000 p.p.m. thiosulfate sulfur to activated sludge, and this elemental sulfur is absorbed by the sludge.

13. Any possible toxic effects of thiosulfate are masked by the continued oxidation of the thiosulfate remaining in the effluent after aeration.

## Acknowledgment

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# FLOW MEASUREMENT IN SEWAGE WORKS*

## III. Secondary Instruments, Controls, Operation, Maintenance

By Walter H. Brown and George E. Symons

*Respectively, Project Applications Engineer, Builders-Providence, Inc., Providence, R. I., and Consultant and Technical Editor, Larchmont, N. Y.*

The previous sections of this treatise† presented material on types of primary flow measuring units and the factors which enter into the selection of primary units. The next step in the design of flow measuring facilities for a sewage works is the selection of secondary instruments, those devices which convert the sensed function of flow into observable information. Other phases of flow measuring include controls, operation problems, and maintenance. The following discussion covers these subjects and makes some mention of other miscellaneous measurements in sewage works.

### Secondary Instruments

The secondary unit of a meter, usually called the secondary instrument (or receiver), is a device used to convert information sensed by and transmitted from the primary unit into data and information desired on flow. (Level of liquid and pressure also can be shown on secondary instruments.) Secondary instruments are classified in two ways: (a) type of information desired, and (b) method of transmission used from primary to secondary instruments.

There are three types of information that can be obtained from secondary instruments, either separately or in any combination, as follows:

1. Indication of flow rate in c.f.s., g.p.m., g.p.h., or m.g.d., as desired.
2. Running total of flow to the observed moment, in cu. ft., gal., or m.g.
3. A drawn record on a chart, showing the rate of flow as a continuous record for each instant throughout the particular period (hour, day, week, etc.)

These instruments are called, respectively, indicator, totalizer, recorder. Combinations of these functions are more common than simple types of instruments, the most common being the totalizer-recorder, although totalizer-indicator-recorders are also quite common in sewage works. The choice of any one of these functions or combinations thereof will depend on the flow being metered, the designer's preference, and the process involved in the plant. For example, a plant influent meter might be a totalizer-indicator-recorder; and aeration tank air meter might be an indicator-recorder; and a digester cover level gage might be a recorder only.

#### *Transmission*

There are three types of secondary instruments, designated according to the method of transmitting the information from primary to secondary instruments. Methods of transmission may be mechanical, electrical, or pneumatic. (Pressure transmission is hydraulic.)

A mechanical meter (Figure 20) is one that is actuated by a float or directly by differential pressure. In float actuation, the instrument is

* Presented at 1954 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; Jan. 21–22, 1954.

† Part I appeared in This Journal, **27**, 2, 149 (Feb., 1955); Part II, in This Journal, **27**, 3, 283 (Mar., 1955).

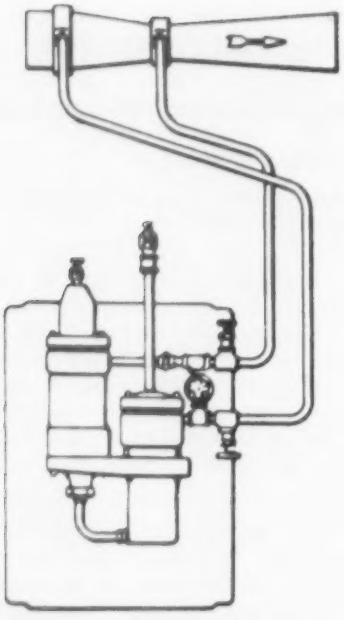

FIGURE 20.—Mechanical meter, direct transmission.

mounted near a stilling well and the change in liquid level is transmitted by means of a float, cable, and counterweight. In differential actuation, pressure pipes are run directly from the differential producer to mercury wells of the secondary instrument.

If the secondary instrument cannot be located near the primary unit stilling well, or if there is insufficient head to utilize direct connection with the secondary instrument, then electrical or pneumatic transmission may be used.

Electrical transmission (Figure 21) is usually of the time-impulse type. The transmitter is a device which contains a cam, a synchronous motor, and a magnetically-operated mercury switch. The cam rotates at a constant speed, usually revolving every 15 sec. As the cam moves, it moves the magnet away from the mercury switch, causing the switch to close. The cam-shoe arm is positioned by the differential pressure of a Venturi tube, etc., level, or Bourdon pressure tube, depending on the function being measured. The length of time that the cam-face rides on the cam-face determines the time the switch is closed and this time interval varies in direct proportion to the magnitude of the variable being measured. The same proportionate signal which actuates a receiving instrument can also be used to control pumps, valves, or chemical feeders.

The output signal from an electric transmitter can be sent over private wire (a.c. or d.c.), over telephone circuits, or over multi-service wires, and can be transmitted any distance from a few feet to many miles. By means of a sequencing device (known as a Sequence Unit Transmitter) signals from several transmitters can be sent consecutively over the same pair

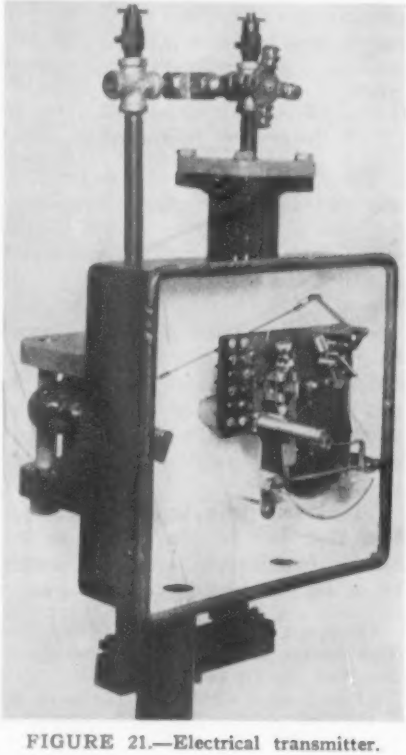

FIGURE 21.—Electrical transmitter.

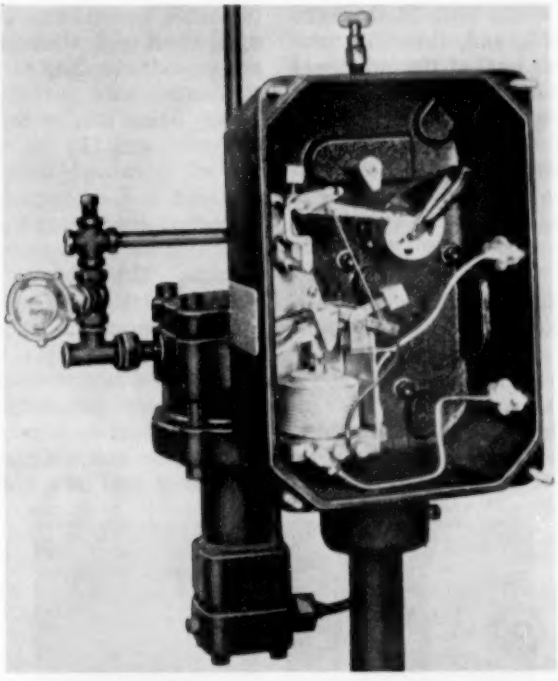

FIGURE 22.—Pneumatic transmitter.

of wires. Sequencing is not often used in sewage works but may be used to control remote lift station pumping operations.

Pneumatic transmission (Figure 22) is frequently used in sewage works because hydrogen sulfide is usually present to some degree and corrosion of electrical contacts and terminals may be a problem. There are many other reasons for its use. The transmitter contains a specially calibrated cam, positioned by a diaphragm or mercury well float, and operates and controls a bleeder valve system and bellows unit to produce an output pressure directly proportional to the rate of flow or liquid level being transmitted. Most pneumatic systems make use of a varying controlled-proportionate-air-pressure ranging from 3 to 15 p.s.i. The principal features of pneumantic transmission are absence of wiring from transmitter to receiver, continuous (rather than intermittent) output signal (pressure), extreme sensitivity to pressure change, simplicity, and trouble-free operation.

*Summation*

It is often desirable to add two or more flow rates of individual units to provide, on a single receiving instrument, a total representing the combined flow rates. This addition is accomplished by a summation unit, either electrical or pneumatic. The electrical-type summator receives signals from time-impulse transmitters and, by means of proper linkages, positions its own time-impulse transmitter to represent the sum of the individual signals.

The pneumatic-type summator receives the output pressure from the individual transmitters, adds them together, and by positioning a re-transmitter, sends out its own air pressure

proportional to the total of the individual pressures, and, therefore, proportional to the total of the individual flows. The output signals or pressures from these summators may be used for metering, control of chemical feeders, proportional pacing of chlorinizers, sluice gate positioning, and other operations.

*Receivers*

Since flow varies as the square root of the head, secondary instruments or receivers are constructed to take the information received and to make necessary mathematical calculations so that the reading will be in the units desired by the operator. This calculation is done in one of two ways: (a) the chart or indicator scale is of the square root type, wherein the divisions are spaced according to the square of the units, with readability and accuracy being best at the high end of the scale; and (b) the receiver has a cam which extracts the square root of the head and converts it to a linear movement, the indicator or chart showing the observation on a linear chart or scale. The latter type of receiver has unit markings of equal length and equally accurate readability at both ends of the scale.

Where indicator-recorders are used, the indicator arm may be separate from the chart or it may be attached to the pen arm. Charts for weirs and flumes read on a linear scale. In-

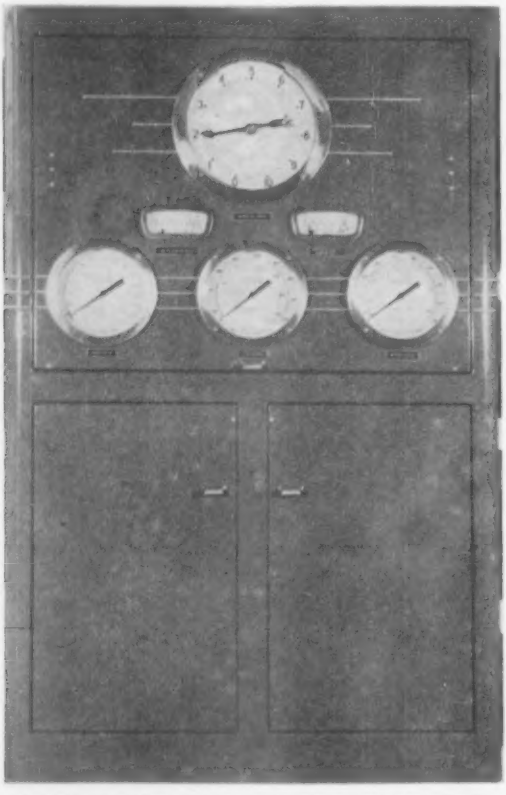

FIGURE 23.—Panel with gages for power generated (top); air-sewage and return sludge-sewage ratios (center); and aeration air, raw sewage, and return sludge (bottom).

dicators only may be round dials, or part of a circle divided as desired, or straight linear scale. Indicator—totalizer combinations have an indicator arm and a counter.

*Flow Ratio Metering*

For the proper control and operation of activated sludge plants, the operator desires to know the relation of air to sewage (cu. ft. of air per gal. of sewage), and the relation of returned sludge to sewage flow or per cent return of sludge. These relations can be calculated from observed data on the flow of each. The relations can also be determined continuously and mechanically by flow ratio metering (Figure 23). For this operation, pneumatic transmitters, summators, and an anti-log computer are used. The anti-log computer receives air pressures representing both air flow and sewage flow (or return sludge and sewage flow) and subtracts the logarithms (existing as pressures) mechanically. The resulting air pressure represents the ratio of the two input pressures, and thus represents the ratio of the flows.

All of the metering devices, primary units, and secondary instruments mentioned heretefore are used for flow measurement in sewage works, including measurements of sewage, sludge, air, gas, and water. Orifices are not used for measuring sewage or sludge.

*Conveyor Scale Metering*

Many waste treatment plants are now being equipped with vacuum filters for the dewatering of sludge. Conveyor systems are usually a part of the installation. A scale mechanism can be incorporated into the conveyor to continuously totalize and indicate the rate of flow of the dewatered sludge solids.

The mechanism weighs the loaded belt passing over it and at the same time subtracts the weight of the return belt, plus any material adhering to the belt, thus maintaining a constant tare; the results are a true net weight of the sludge cake. The method of operation of the weighing system is pneumatic; when properly installed, accuracies of approximately 99.5 per cent of the actual weight can be obtained.

Total weight and rate of flow of the sludge are extremely useful data for determining filter operation efficiency and for the proper control of incinerators used in the final disposal of sludge.

*Controls*

Meters are extremely useful in providing control of flows, chemical feeding, proportioning, pumping, sampling, and other operations. Control can be accomplished by electrical, pneumatic, or mechanical means.

When using an electrical system, contacts are provided to be made after a predetermined number of gallons have passed or when the flow reaches a predetermined rate. Timers may be used with proportional sampling systems. Pneumatic systems are often used because the output air pressure from the rate of flow transmitter is continuous, thereby minimizing the time of response of the controlled unit. Straight mechanical control is usually limited to the operation of valves and pumps.

With the high cost of labor and the difficulties of obtaining operating personnel, it is desirable in a sewage works to keep operating chores at a minimum. For this purpose, centralized control (Figure 24), with many receivers in one place, is a good method of meeting the problem. Electrical or pneumatic transmission makes centralized control possible.

*Selection of Secondary Instruments*

In the choice of secondary instruments there are a number of factors to be considered and a number of questions to be answered, as follows:

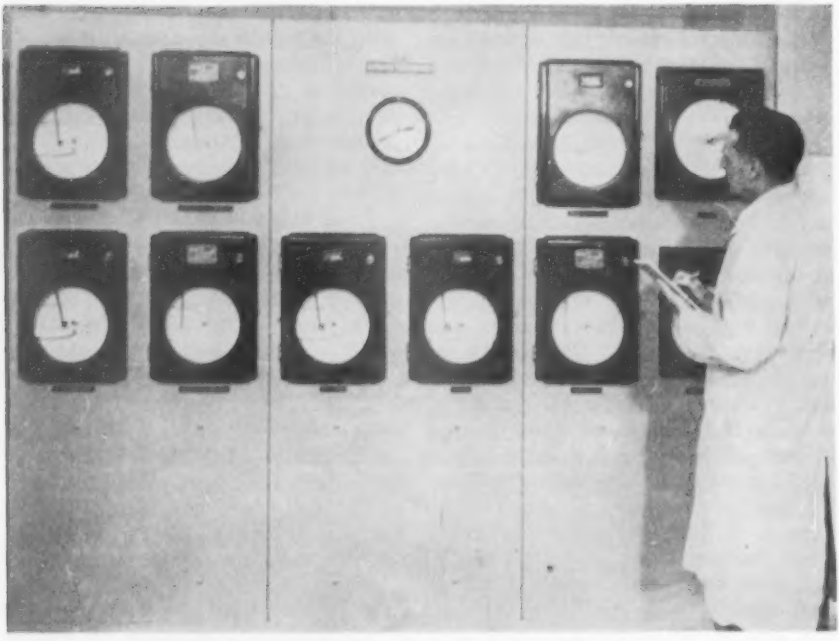

FIGURE 24.—Centralized control panel in large sewage works. Meters include units for influent flow, air, chlorine, pH, temperature, and sludge.

1. The type of primary device selected (weir, Parshall flume, Venturi tube, nozzle, orifice, etc.) dictates the method by which the secondary device is operated, whether single float, differential float, or differential U-tube (that is, differential pressure).

2. The range of flows to be metered must be known; that is, the range of maximum to minimum flow as 4 to 1 or 10 to 1.

3. Desired accuracy. Accuracy depends not only on the primary instrument, but also on the combination of primary and secondary units. Data are available from manufacturers giving normal accuracy expectations *versus* type of service.

4. The relative location of the selected points of installation of the primary and secondary units has a bearing on whether the transmission can be by direct connected, float operated cable, or by direct pressure connections, or whether distance transmission is required, and which of the two distance types of transmission is more desirable.

5. Type of information desired, whether total flow, indicated flow, or recorded flow, or combination (or level or pressure), dictates the type of secondary instrument.

6. Future capacity of the plant and meter and the maximum to be expected have a definite bearing on the size of meter chosen.

7. Expected life of instrument. Will the purchaser be satisfied with obsolescence in a few years or desire an instrument which will outlive the life of plant financing bonds?

8. Secondary functions, if any, to be performed by these meters, such as pacing chemical feeders or ratio control.

## Operating Problems

Many problems arise in the operation of flow measuring equipment. It is impossible to discuss all that have been reported, but a few of the more common types of problems are worth mentioning.

### *Negative Head*

Negative head (Figure 25) is a condition which may occur in a differential producer if installation is improper. It occurs when the liquid pressure inside either or both mercury wells of a differential producer instrument is less than atmospheric. When this happens, air may enter and become trapped in the pressure lines or wells, thereby causing serious errors in the readings. When the head in a pipeline is insufficient to keep a positive pressure on both wells of the instrument under all conditions, a transmitter at a lower elevation must be used, or float pipes may be used as an alternate to mercury wells, or the secondary instrument may have to be moved to a lower position.

### *Foreign Bodies*

Foreign bodies often find their way into measuring devices both during construction and during operation. Any foreign body will adversely affect operations of all measuring devices. Solids which build up behind or on the edge of weirs and orifices cause errors in reading. A variety of objects have been removed from Venturi tubes, including a piece of wood, a small shark, jute for caulking, a chunk of Leadite, a wad of rags, a blank wood flange, a chunk of concrete, grease deposits, bolts and nuts, a bucket, bricks, a sledge hammer, overalls, a ring gasket, and grease balls. The only remedy for this situation is to use care to prevent the entrance of such bodies and to remove them when they appear.

### *Deposits*

Deposits on the surfaces of a primary device (as, for example, the deposition of grease or calcium soaps or the growth of slimes on weir and orifice edges and surfaces of other

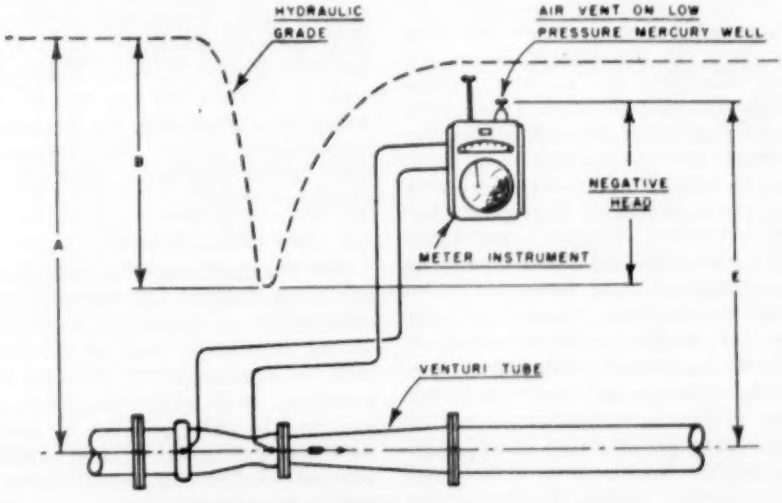


FIGURE 25.—Example of negative head.

differential producers) will cause a change in flow characteristics of the device and readings will be incorrect. Cleaning is the remedy.

*Wear, Moisture, and Erosion*

Wear on transmitter or receiver parts, especially if the wear is on a cam, will cause the apparent reading to vary from the true reading.

Moisture in the receiver may cause wrinkling of the charts. Protection against the elements or some means of keeping the chart dry, as by a light bulb or heating element in the housing, has solved the problem.

Erosion of the walls of a primary device may be caused by the presence of sand and gritty particles in the sewage. Continual wearing away of the lining of the device will change its flow characteristics and cause a decrease in accuracy.

*Pulsating Flow*

Pulsating flow is the most difficult flow to meter in a modern waste treatment plant. This type of flow occurs where reciprocating pumps or lobe-type blowers are used. The differences between these two cases is significant. It is not as difficult to meter a pulsating liquid flow as it is a pulsating gas flow. In the case of air or gas flow, examples can be given where differential meters indicate a considerable flow when the end of the line is closed and there could be no flow. This is caused by a standing wave pattern resonating in the closed pipeline. The effect of a particular pulsation on a differential meter measuring a compressible fluid is impossible to predict, except for the simplest system. If the flow must be measured, it is wise to install a compressor producing a continuous or non-pulsating flow.

Accurate measurement of a pulsating liquid flow with a differential meter is often possible, but depends to a large extent upon the form of the pulsations. The principal error in measuring this type of flow comes from the fact that the meter senses an average differential and indicates a flow based on this average differential. The true average flow, however, depends on the average of the square root of the differential and in most cases, the average of the square root of the differential is not equal to the square root of the average differential. The error introduced by this situation often can be calculated and the readings corrected accordingly. Each individual case must be analyzed by itself and equipment designed to handle the problem.

## Maintenance

Meters can be a costly luxury without a proper maintenance program because meters are of little, if any, value unless they are accurate. Maintenance of accuracy requires a proper maintenance program. The fundamentals of preventive maintenance have been set forth by Ward (13) and have been reduced to a handy outline form (14). The principle points, in brief form, are set forth in the following.

Preventive maintenance is insurance against costly breakdowns. All equipment needs maintenance. Good maintenance involves proper knowledge, tools, and parts for its proper performance. Furthermore, preventive maintenance means that equipment must have reasonable attention at regular intervals.

*The Instruction Manual*

The first step toward an understanding of the construction, operation, and adjustment of equipment is a study of the instruction manual furnished with the equipment. If there are any questions, write to the manufacturer, who will be only too glad to answer questions and assist in any possible manner. Index and file all manuals, so that anyone can identify and readily find the manual desired.

*Tools*

Special tools, which may be required for maintenance operations, generally are furnished with the equipment. If these special tools have been mislaid, write to the manufacturer for a quotation on a replacement set. These tools are not costly, but are invaluable, inasmuch as most of them are especially suited for the adjustments to be made.

These tools should be located in a specific place, preferably in a wall cabinet, handy to the equipment. Each tool should be labelled as to the equipment for which it is to be used.

*Spare Parts*

Decide what spare parts should be on hand to insure prompt repairs and continuous operation of the equipment. Spare parts recommended by the manufacturer usually will be found listed in the instruction manual. This list represents the minimum number of spare parts which should be stocked.

Spare parts should be labelled carefully and kept with the special maintenance tools. If lubricants recommended by the manufacturer are not obtainable locally, write the manufacturer for a supply, or for the name of a substitute which can be obtained locally.

*Preventive Maintenance Schedule*

The next step is to establish a preventive maintenance schedule. If recommended maintenance procedures are not in the instruction book, write the manufacturer for his recommendation. A sound maintenance schedule will include arrangements for a regular visit of a factory-trained field service man, once or twice a year.

*Maintenance Records*

Establish a card file (or book) with a card for each piece of equipment. Each record card should show the type of equipment, the manufacturer's serial number, the date installed, the location, etc.

Set up the maintenance schedule on the card, showing what operations are to be performed and at what time of year. Arrange the file of maintenance cards so that the card for each particular piece of equipment will come to the operator's attention automatically on the date established for maintenance work on that equipment. Transfer any information on trouble shooting from the instruction manual to a card; if too voluminous, indicate on the card the location of the instruction manual.

Provide a space on the card, beside the operation required, for the initials of the person who performed the operation and the date of completion. List on the card the lubricants specified by the manufacturer. Enter on the card any unusual maintenance operation performed to remedy trouble. This simplifies the job for the next person who may run into the same trouble. Enter on the card all parts and emergency service calls, and cost of each so that (a) further parts requirements may be anticipated, and (b) there will be an indication of the desirability of replacing obsolete or worn out equipment.

*Preventive Maintenance Operations*

Safeguard operators through observance of safety precautions, and protect the equipment itself against possible damage by operators or passers-by, or injury from any cause whatsoever. Operate standby equipment at regular intervals; also, any equipment used at relatively infrequent intervals. Inspect the condition of the equipment, its efficiency of operation, and the accuracy of its performance. Clean the equipment, using the correct method or cleaner as indicated in the instruction manual. Lubricate with proper kind and correct quantity of lubricant. Replace all parts showing definite wear which will

interfere with accurate performance of the equipment. Paint the surface. Overhaul, disassemble, clean, lubricate, replace worn parts, paint, assemble, and test. Use the manufacturer's Maintenance Service Plan.

*Special Precautions*

Treat equipment with the respect due it. Handle it carefully; rough handling may injure or disturb its operation. Use the correct tools for repairs; don't use a Stillson wrench when an open end or adjustable wrench is indicated. Don't abuse equipment; it is designed to perform certain functions or operations efficiently and at reasonable cost. Don't force it to do more than the job for which it was intended. Above all, don't neglect equipment.

Speaking on the subject of "Preventive Maintenance" Ward (15) made these comments:

> An efficient maintenance program can minimize repair and/or replacement charges. In the maintenance of primary devices, periodical visual inspection will show possible troubles. In maintaining the secondary instrument, visual inspections at regular intervals will indicate not only actual trouble, but also impending trouble.
>
> Where skilled personnel are available, the meter calibration should be checked periodically. Minor repairs should be made at once, but only by a competent person. An untrained repairman can do more harm than good. Broken or damaged parts should be replaced as soon as possible. Minor adjustments should be made with extreme care. Moving parts should be lubricated strictly according to the manufacturer's instructions.
>
> A definite maintenance program should be established and adhered to, with the aim of top meter efficiency at lowest possible cost. Repairs, adjustments, and calibrations should be made only by those qualified. Otherwise, costly damage can occur. The manufacturer of the metering device is as much interested as the operator in seeing that the installation operates at top efficiency and at the lowest cost. Do not hesitate to call on him for service and help in training your own maintenance men.

## Other Measurements

Table I (Part I) listed five miscellaneous flow measurements and seven miscellaneous measurements other than flow, all of which are frequently made in sewage works. Probably the most general measurement of these groups is that of electricity, both for individual units and for total plant consumption. Other flows frequently measured are plant water, potable water, and oil and gas consumption. Meters for oil, water, and gas measurement may be differential producers or displacement meters, depending on the size of the flow and the particular installation. Electricity measurement is not by a fluid flow metering device.

Measurements other than flow are usually temperatures of sewage or digesters, or observations on the weather (temperature, barometric pressure, precipitation, wind velocity, and direction). Other measurements are pressures of fluids in closed lines (gas, oil, water, and sewage) and levels in digesters or other storage tanks. Gas concentration is frequently measured in confined areas as a safety measure, with an alarm device attached to the sampling and detecting device.

## Summary

It has been the purpose of this treatise to present the fundamentals of flow measurement in sewage works in a manner designed to make it possible for new operators and students to become acquainted with the subject, and for others to review these fundamentals without recourse to a wide assortment of articles and text books.

## Acknowledgments

The authors are deeply indebted to various staff members of B-I-F Industries, Inc., for making available notes and ideas that have been used elsewhere. Particular thanks are due

to George Clausson for his material on fundamentals of flow measurement (10); and to I. O. Miner, John Ward, R. W. Pearce, and F. H. Cary, all of Builders-Providence, Inc., for helpful suggestions and material.

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Members of any of the three collaborating organizations that jointly prepared the publication may obtain the Tenth Edition of "Standard Methods for the Examination of Water, Sewage and Industrial Wastes" at a special price of $6.50, provided remittance accompanies the order. Otherwise the regular price of $7.50 will obtain for the 522-page volume.

See front inside cover of this issue for details.

FEDERATION HEADQUARTERS OFFICE MOVED

By the end of April 1955, the Federation headquarters and publication office will be moved from its present location in Champaign, Ill., to new quarters in Washington, D. C. See page 513 for details.

# Industrial Wastes

## THE ANAEROBIC CONTACT PROCESS AS APPLIED TO PACKINGHOUSE WASTES*

By George J. Schroepfer, W. J. Fullen, A. S. Johnson, N. R. Ziemke and J. J. Anderson

*Respectively, Professor of Sanitary Engineering, University of Minnesota; Chemist, Geo. A. Hormel & Co., Austin, Minn.; Instructor in Civil Engineering, University of Minnesota; Instructor in Civil Engineering, University of Minnesota; and Project Engineer, American Meat Institute, Chicago, Ill.*

For the past four years pilot-plant investigation of the anaerobic treatment of packing plant wastes has been underway at the Geo. A. Hormel & Co. plant at Austin, Minn., under the direction of W. J. Fullen, Chemist. These studies, begun on barrel scale, were enlarged in 1950 to the present pilot plant treating an average of approximately 7,000 g.p.d.

In March 1952, the Committee on Meat Packing Plant Waste Disposal of the American Meat Institute, under the Chairmanship of M. D. Sanders,† requested Professor Schroepfer to analyze and evaluate the data available on the process at Austin.

As a result of this analysis and evaluation, a report was presented to the Committee on July 1, 1952. This report analyzed the data collected over a two-year period of operation of the pilot plant. As a part of the evaluation of the process, a comparison was made of the costs of this process at the then practiced loadings with those of conventional aerobic processes. The report concluded with recommendations for further investigations of a number of questions which had arisen as a result of the preliminary studies. After a three-month study, the Committee on October 2, 1952, recommended a one-year program of research investigations based on the July 1, 1952 report, and this recommendation was approved by the Board of Directors of the Institute on October 6, 1952.

The pilot plant was remodeled during the period from July 1 to October 1952. This work included installation of a new method of sludge separation embodying evacuation, the advantages of which were indicated as a result of the previous investigation.

The actual research test program was begun in October 1952. A number of preliminary tests occupied the period from October to December 1952, when the basic test program was begun. The program included a series of tests to determine the effect of organic loading and detention period on the efficiency of the process. A number of ancillary investigations were conducted, including the removal of nutrients, the deoxygenation constant of the effluent, the effect of the nitro-

* Presented at 27th Annual Meeting, Federation of Sewage and Industrial Waste Assns.; Cincinnati, Ohio; Oct. 11–14, 1954.

† Other members of the Committee are G. A. Aikins, Armour and Company, presently Chairman; W. S. Sturges, The Cudahy Packing Co.; W. J. Fullen, Geo. A. Hormel & Co.; V. R. Rupp, Kingan, Inc.; John A. Eckstein, Oscar Mayer & Co.; C. E. Gross, John Morrell & Co.; A. J. Steffen, Wilson & Co., Inc.; F. W. Sollo, Swift & Company, replacing Mr. Sanders; and H. D. Tefft, American Meat Institute.

gen present on long-time B.O.D. removals, the thermal requirements of the process, etc. All of the basic tests during this year involved the use of fly ash as a weighting additive to improve separation and sludge concentration. This investigation was incorporated in a report dated September 1, 1953.

As a result of this report an additional year of investigation was authorized by the Institute, which covered the period from September 1953 to August 1954. All of these tests were conducted without fly ash as an additive. In addition to the basic tests on the effect of loading, series were conducted on the effect of temperature, of degree of mixing, and of degree of vacuum to which the digester effluent was subjected. A test on the effect of a variable raw feed such as would be experienced without a holding tank also was carried on. Preliminary laboratory tests on flotation resulted in the construction and testing of a pilot-plant flotation unit. Supplementary investigations carried on during the year included studies of the behavior of anaerobic effluent when applied to a trickling filter, gas analysis and quantity determinations, odor studies, sludge dewatering characteristics, power requirements of evacuation, determination of the settling characteristics of the solids, etc.

The investigation of the process naturally divides into four periods under which the data are reported, as follows:

1. The early tests from July 1950 to September 1952, during which separation was generally unsatisfactory.

2. The preliminary tests from October to December 1952, in which a new separation process was employed consisting of evacuation followed by efficient gravity settling. This system was used in all subsequent tests.

3. The 1953 research test program covering the period from January to August 1953, in which fly ash was employed.

4. The 1953–4 research test program, which included the interval between September 1953 to August 1954, conducted without benefit of additives.

### *Conduct of Investigations*

As previously indicated, direct supervision of the operation of the pilot plant was the responsibility of Mr. Fullen, who perceived the possibility of digestion of packing plant wastes in 1949. Geo. A. Hormel & Co. provided the pilot-plant facilities and financed practically all of the improvement changes and operation and maintenance costs. In addition, the company provided the services of Frank Orlowski, chemist, who performed essentially all of the analytical determinations.

From March 1952, when the American Meat Institute became interested in the project, Professor Schroepfer was engaged to plan a program of research tests and to analyze and evaluate the results thereof. He had as his associates on the project Messrs. Johnson and Ziemke. From January 1953 to the completion of the test program, the American Meat Institute provided the services of Mr. Anderson on a full-time basis to assist in conducting the tests.

## Description of Pilot Plant

### *Pretreatment Facilities*

The raw wastes from the Geo. A. Hormel & Co. plant are first screened in units with ¾-in. clear openings. The wastes then enter a clarifier which serves as a grit and grease removal unit. The clarifier is 25 ft. in diameter and has an 8-ft. 2-in. sidewall depth. The theoretical detention period, based on an average flow of 2.3 m.g.d., is 19 min. Sludge is pumped from the unit continuously during the day. Grease skimmed continuously from the surface flows to a sump. The influent to the pilot plant is withdrawn from

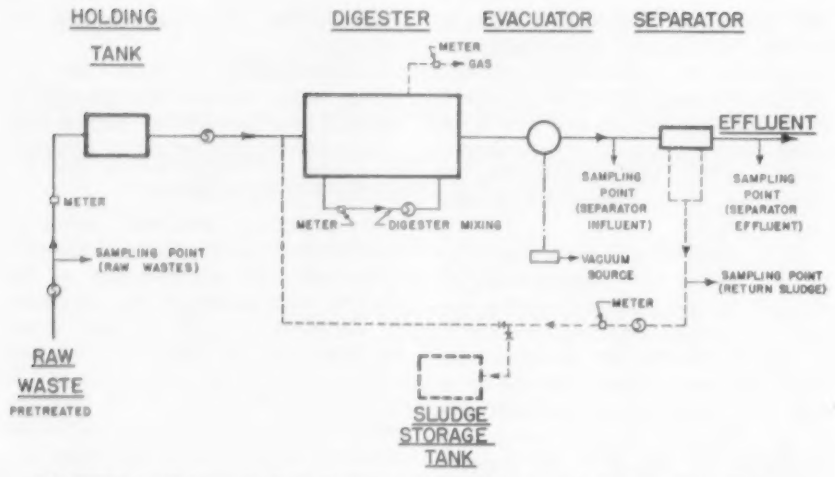


**FIGURE 1.—Schematic flow diagram of anaerobic contact process as applied to packinghouse waste.**

a point near the periphery of this tank at approximately mid-depth.

*Pilot-Plant Units*

1. General—In the construction of the pilot plant, existing square tanks were utilized to provide a holding tank, a digester and, in the early tests, a settling or separator tank. A schematic flow diagram of the process as constituted in 1953 and 1954 is shown in Figure 1.

2. Holding tank—The uncovered holding tank is 8 ft. square in plan, with vertical walls approximately 6 ft. high. The wastes are drawn from the hopper bottom and pumped to the digester through a constant-head feed box.

3. Digester—The digester is approximately 16 ft. by 8 ft. in plan, with vertical walls 6 ft. high and double hopper bottom. Digester contents are heated by passing the continuous digester mixing flow through a heat exchanger. Gas is collected from a gas dome at the top of the covered tank and is metered.

The digester contents are constantly mixed by a pump which draws digester contents from the bottom of each of the two hoppers. The discharge of this pump is approximately 15,250 cu. ft. per day. The discharge is directed at high velocity against two 6-in. diameter plates above the liquid surface in the digester.

4. Evacuation tank—The 2½-ft. diameter insulated and elevated steel evacuation tank is supported at an elevation such that flow from the digester overflow box will rise to it when the tank interior is subjected to a vacuum of 20 or more inches of mercury. The discharge line from this unit leads to the constant-head box for the separator. This box is at an elevation such that the liquid level in the evacuation tank discharge line will be below the splash trays in the evacuation tank at all vacua up to 27 in. of mercury. The six levels of splash trays in the evacuation tanks are so arranged that the influent to the tank must pass over each tray in the cascade so as to provide a large surface area of liquid subjected to a vacuum. This unit was replaced on January 2, 1954, by a new unit having approximately the same characteristics.

5. Separation tank—This unit is a steel tank 8 ft. long by 4 ft. wide with a liquid depth of 2 ft. 11 in. Influent from a feed box enters through six 1-in. holes in a 2½-in. pipe which extends across the full width of the tank at mid-depth at the influent end. A slat-type baffle at the influent end of the tank aids in uniform distribution of the flow. Effluent from the unit is collected in a trough equipped on each side with V-notch weirs. Total weir length is 8 feet. Sludge removed from the unit by a traveling hydraulic sludge removal device is pumped to the digestion tank (Figure 2).

6. Trickling filter—The trickling filter is an 8-ft. diameter steel tank containing 4.75 ft. of media. The motor-driven distributor arm consists of a trough with V-notch weir cut in the sides spaced so as to distribute the flow evenly over the 2- to 4-in. trap rock media.

7. Flow measurement—Raw feed and return sludge from the separator are continuously metered as discharged to the holding tank. The digester mixing line is equipped with a meter for measuring the flow. All meters are disc-type water meters with the screens removed.

8. Sampling methods—Continuous sampling devices were installed prior to January 1953. Two types were employed, depending on the situation. On the raw feed where the pumping to the equalizing tank was intermittent, a ½-in. solenoid valve (timer operated) was employed. This sampler operated 8 sec. during each 2 min. of raw feed pump operation.

At the three other sampling points it was possible to employ dip samplers, which rotated at a uniform speed of 2 r.p.m., as the flows treated were always equal in quantity between sampling intervals.

## Accomplishments in Early Tests

In analyzing the results in the period from July 1950 to September 1952, the data were broken down into separate periods, depending on the method of operation employed. The

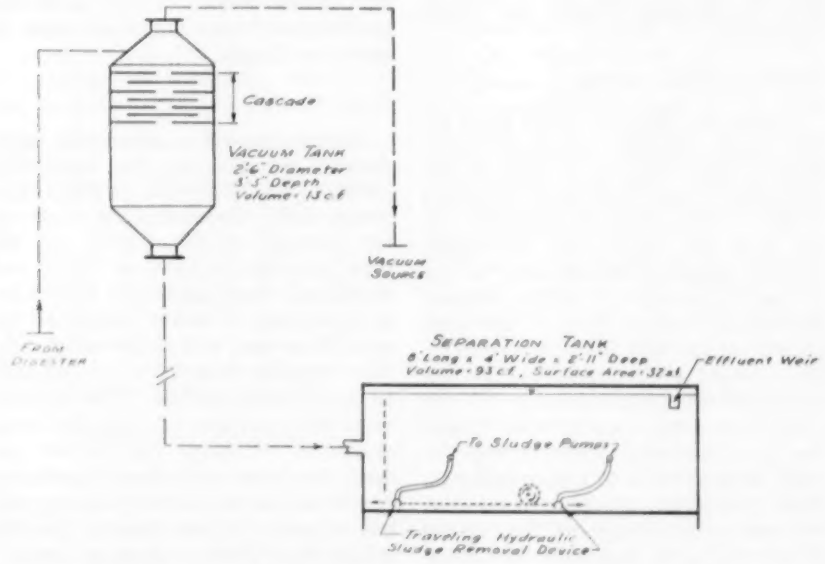


FIGURE 2.—Schematic diagram of evacuation and separation stages.

loadings on the process ranged between 0.04 and 0.05 lb. of B.O.D. and total volatile solids per cubic foot per day. At these loadings, removals of approximately 95, 80 and 75 per cent in B.O.D., suspended solids and total volatile solids, respectively, were accomplished. Average detention periods of 1¼ to 2½ days were required to secure these removals.

The principal problem confronting the process in all of these preliminary tests was that of separating the solids from the liquid after digestion. This problem was so serious that it was considered the principal stumbling block to a satisfactory process in the July 1, 1952 report, in which it was recommended that this be the number one item in a further investigational program.

## Preliminary (1952) Tests

Following authorization of a research investigation of the process, a number of studies preliminary to a program of actual tests were initiated. Before discussing these, a review of the existing status of the process at the time the research project was begun is in order.

### *The Separation Problem*

During the two-year period since the pilot plant was first placed in operation in July 1950, to the date of the evaluation report previously discussed (July 1, 1952), separation of the solids from the liquid was the major problem affecting the efficiency of the process. Even though B.O.D. removal efficiencies of about 95 per cent were possible at the then practiced loadings, the removal of suspended solids was relatively low (approximately 80 per cent), indicating, among other disadvantages, difficulties with holding the solids in the system at higher loadings. Preliminary tests reported in the first evaluation study suggested the efficacy of evacuating the gas from the sludge as a means of improving separation. These tests indicated that this procedure was very promising in solving the problem of gas lifting of some of the sludge particles. Accordingly, during the period from July 1 to September 1, 1952, devices for evacuation of the gas on a continuous flow basis, followed by sedimentation in a tank equipped for continuous sludge removal of the hydraulic suction type, were designed and constructed (Figure 2).

The new separation process was placed in operation on September 2, 1952. An indication of its efficiency is the fact that the removal of suspended solids by the entire process in the period from September 2 to December 25, 1952, increased to 95.6 per cent from its former average value of 80 per cent. The effectiveness of the evacuation and separation process alone can be illustrated by these average values for the same period. The suspended solids in the influent to the separation tank averaged 10,630 p.p.m., with an effluent of 37 p.p.m., indicating an average efficiency of 99.6 per cent. The flow diagram of the process during this period, as well as during the research tests described later, is shown in Figure 1.

### *Concentration*

Having reached a reasonably satisfactory solution to the separation problem, an additional problem presented itself. Because of the relatively low average specific gravity of the solid particles (average of 1.39 in two tests) and other conditions, the sludge as withdrawn from the bottom of the separation tank was of low solids content (ranging from 1.2 to 1.6 per cent in the different periods). This necessitated the pumpback of relatively large quantities of sludge (up to 300 per cent of the raw waste flow), involving, in addition to the cost of pumping, the use of space in the digester for this added flow. The problem of concentration was basically an economic one,

since the process performed satisfactorily as it was. Several methods of concentration were considered to solve this problem. For the existing installation it appeared that the use of a weighting additive such as fly ash, which is generally available, was the most feasible. Accordingly, jar tests involving the addition of various amounts of fly ash were conducted, from which it was indicated that the addition of 100 per cent by weight of fly ash of the dry suspended sewage solids was a desirable value. For the detention periods provided, little more in the way of concentration could be gained by increasing the additive. This addition resulted in an average specific gravity of the solids in three tests of 1.96, increasing the hydraulic subsiding value of the particles (assuming a particular diameter) by 250 per cent.

Reinforced by the results of the small-scale jar tests, 560 lb. of fly ash were added to the holding tank of the pilot plant. This amounted to approximately a 100 per cent addition to the 537 lb. of suspended solids in the system. The effect of this addition on solids concentration for a settling time of 40 min. in jars (mean time of passage in separator, 36 min.), can be summarized as follows:

| Time after Ash Addition (hr.) | Reduction in Sludge Volume (%) | Susp. Solids in Sludge[1] (%) |
|---|---|---|
| 0 | — | 1.11 |
| 1.75 | — | 1.25 |
| 3.50 | 12.0 | 1.40 |
| 8.00 | 25.5 | 1.68 |
| 21.50 | 32.0 | 1.82 |
| 22.50 | 32.0 | 1.83 |

[1] Excluding fly ash.

### 1953 Test Program

Prior to the initiation of any basic tests as part of this research, a program of eleven tests was recommended to and approved by the Committee. Except where developments indicated the desirability of additional tests, the original program was adhered to.

To insure the satisfactory conduct of the tests according to the planned program and time schedule, it was necessary to detail and to follow certain routine operations of checking the various items of equipment and of recording and analyzing data. In view of the fact that a number of factors influence the efficiency of the process, it was also necessary in planning the program to consider which of these factors were to be variables and which constants in the various tests. Since the effect of loading was paramount, and would mask wholly or to a large extent some of the other factors, this was considered to be the prime variable for the early tests. This is made up of (a) the quantity and (b) the strength of the raw feed. Other influencing factors are (c) the temperature of digestion, (d) the degree of mixing in the digester, (e) the vacuum maintained, (f) the percentage of fixed solids in the system, (g) hourly variations in organic load in raw feed, (h) the volume of the digestion tank as related to the raw loading, (i) the concentration of solids in the digester and the related sludge age, (j) the pumpback of return sludge (quantity and characteristics), and (k) the level of sludge in the separator. In the first series of tests on loading factors, all except items d, h and j were planned as constants, these three being necessary variables.

So an early concept of the program of tests may be had, the following summary is presented. The first series of tests provided for variable planned loadings of 0.10, 0.15, 0.20 and 0.25 lb. of B.O.D. per cubic foot of digester capacity per day, to show the loading-removal relationship of the process. This series was conducted at 95° F., with an attempt to maintain constant the quantity of the raw wastes at 900 cu. ft. per day and the strength at 1,600 p.p.m. of B.O.D. and

total volatile solids. Following series 1, a number of further tests on such factors as the effect of temperature, strength of raw wastes, variations in hourly load, degree of mixing, vacuum maintained, weighting additives, supplementary treatment of effluent, etc., were conducted. At the same time, investigation of a number of supplementary factors affecting or involved in the process was carried on.

*Description of Tests*

A more detailed description of the eleven tests which began on January 14, 1953, and continued to August 1953, with a discussion of the test objective, follows:

As applied to all of the tests (except where the effect of this factor was being determined) the volumetric loading on the pilot plant was maintained at a relatively constant value of 900 cu. ft. per day. This was done to reduce the effect of volumetric loading on the efficiency of the separation process, which has a rather definite capacity from a performance standpoint.

Another general statement which applies to all of the tests relates to waste strength. While the aim was to maintain a constant strength during the 24 hr. (except in one test in which the effect of variations in strength were being measured), this could not be accomplished fully because of the variations in strength during the day and night inherent in wastes from this industry and the limitations of the equalizing tank volume. The strengths reported are the average for the 24 hr., with the daytime strengths being approximately 100 per cent greater than the night values.

All of the tests (except Test 5, where the effect of a lower temperature was being determined) were conducted at an average digester temperature of 95° F. Although an attempt was made to operate at the same vacuum (25 in. Hg) in all of the tests, because of physical limitations in the construction this factor necessarily experienced some variations (from 25 in. to 27 in.) at different digester volumes.

It should also be pointed out that of necessity the test periods were relatively short, usually covering a period of two weeks. Further tests over a longer period would be desirable. An encouraging note in this regard, however, is the fact that it was possible to proceed from one test to the next, involving quite some variation in conditions, without appreciable effect on efficiency. It was first planned to provide a week or two between tests to allow equilibrium conditions to be set up. An examination of the analytical data did not indicate this to be necessary, the usual interval being a day or two, and this was usually occasioned by physical changes in the pilot-plant units or repairs to equipment.

During all of the tests reported in this series, weighting material in the form of fly ash was added. The aim was to maintain a constant percentage of fixed solids in the system. This was accomplished reasonably well, as shown by the fact that the percentage of fixed suspended solids in the return sludge averaged 41.8 per cent, with the maximums and minimums in the various tests ranging from 45.0 to 38.8 per cent, respectively. To accomplish this a total of 1,048 lb. of fly ash was added during the entire test period, which amounted to approximately 25 per cent of the 3908.8 lb. of suspended solids in the influent to the system.

To reduce the effect of a variable concentration of volatile solids in the system, an attempt was made to maintain a fixed concentration of total volatile solids in the separator influent at a preselected value of 8,500 p.p.m. Previous tests indicated this to be a satisfactory value, although not necessarily the optimum one. Further tests to indicate optimum values at

TABLE I.—Summary of Results on Effect of Loading (with Fly Ash); Series No. 1, Tests 1–4

| Item | Test 1 | Test 2 | Test 3 | Test 4 |
|---|---|---|---|---|
| Volume, raw feed (cu. ft./day) | 911 | 978 | 890 | 867 |
| Volume, return sludge (cu. ft./day) | 1,383 | 2,084 | 2,447 | 2,595 |
| Recirc. ratio (return sl./raw feed) | 1.52 | 2.23 | 2.75 | 2.95 |
| Vacuum (in. Hg) | 25.0 | 25.0 | 25.9 | 27.0 |
| Total vol. solids, raw (p.p.m.) | 1,487 | 1,508 | 1,523 | 1,451 |
| Total susp. solids, raw (p.p.m.) | 908 | 769 | 817 | 746 |
| 5-Day B.O.D., raw (p.p.m.) | 1,607 | 1,641 | 1,620 | 1,535 |
| Total nitrogen, raw (p.p.m.) | 154 | 151 | 142 | 134 |
| Dig. loading, raw feed (lb./cu. ft./day): | | | | |
| 5-day B.O.D. | 0.100 | 0.153 | 0.192 | 0.240 |
| Total vol. solids | 0.093 | 0.141 | 0.181 | 0.227 |
| Total suspended solids | 0.057 | 0.072 | 0.097 | 0.117 |
| Detention period, digester (hr.): | | | | |
| Raw flow | 24.0 | 16.1 | 12.6 | 9.6 |
| Total flow | 9.2 | 5.1 | 3.4 | 2.4 |
| Detention period, separator (hr.): | | | | |
| Raw flow | 2.45 | 2.28 | 2.51 | 2.60 |
| Total flow | 0.97 | 0.73 | 0.67 | 0.62 |
| Return sludge, susp. solids (p.p.m.) | 19,080 | 24,133 | 19,811 | 17,870 |
| Return sludge, fixed solids (%) | 39.5 | 45.0 | 42.5 | 42.8 |
| Separator infl. (p.p.m.): | | | | |
| Total vol. solids | 7,318 | 9,261 | 9,024 | 8,570 |
| Total susp. solids | 12,616 | 17,038 | 15,680 | 15,210 |
| Separator effluent (p.p.m.): | | | | |
| 5-day B.O.D. | 60 | 52 | 70 | 141 |
| Total vol. solids | 216 | 205 | 261 | 318 |
| Total susp. solids | 15 | 20 | 15 | 58 |
| Removal (%): | | | | |
| Total vol. solids | 85.5 | 86.4 | 82.9 | 78.1 |
| Total susp. solids | 98.4 | 97.4 | 98.2 | 92.3 |
| 5-day B.O.D. | 96.3 | 96.8 | 95.7 | 90.8 |
| Total nitrogen | 25.7 | 27.2 | 36.9 | 32.2 |
| Test period | 1/14/53 to 1/27/53 | 2/2/53 to 2/15/53 | 2/19/53 to 3/9/53 | 3/10/53 to 3/25/53 |

certain loadings near those which might be used in design should be conducted, since this has a bearing on the economics of the problem. Some difficulty was experienced in maintaining this factor constant in the various tests. The average value for all of the tests was quite close to the preselected value, being 8,836 p.p.m., but in the different tests the values ranged from 7,318 to 10,260 p.p.m.

All test data reported in the various sections of this report include only weekday results (Monday to Friday, inclusive), with holidays excluded. The full week results are very close to weekday values.

*Series No. 1*

Under Series 1, four tests were conducted. The purpose of this series was to show the effect of loading on the efficiency of the process. To accomplish this, the effective volume of the digester was varied, but all other factors influencing the process were maintained as constant as practicable. Thus, an attempt was made in this series to maintain an average influent strength of 1,600 p.p.m. of B.O.D. Actually, the average values during the four different tests in this series varied from 1,535 to 1,641 p.p.m.

There was one influencing factor which unfortunately could not be

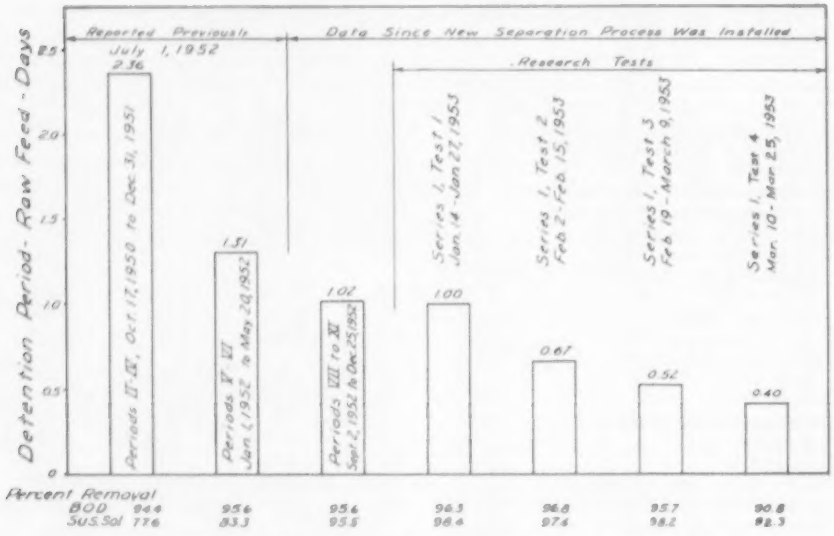
Detention Period - Raw Feed - Days
Reported Previously
Data Since New Separation Process Was Installed
Research Tests
July 1, 1952
2.36
Periods II-IX, Oct 17, 1950 to Dec 31, 1951
1.31
Periods X-XII Jan 1, 1952 to May 20, 1952
1.02
Periods VIII to XI Sept 2, 1952 to Dec 25, 1952
Series 1, Test 1 Jan 14 - Jan 27, 1953
1.00
Series 1, Test 2 Feb 2 - Feb 15, 1953
0.67
Series 1, Test 3 Feb 19 - March 9, 1953
0.52
Series 1, Test 4 Mar 10 - Mar 25, 1953
0.40
Percent Removal
BOD 94.4 95.6 95.6 96.3 96.8 95.7 90.8
Sus. Sol 77.6 83.3 93.5 98.4 97.4 98.2 92.3

**FIGURE 3.—Detention periods provided in various tests.**

maintained constant during this series, and that was the degree of mixing. Since the digester volume was decreased in the different tests of this series, and the mixing pump had a definite capacity and could not be throttled for practical reasons, the number of turnovers of the digester

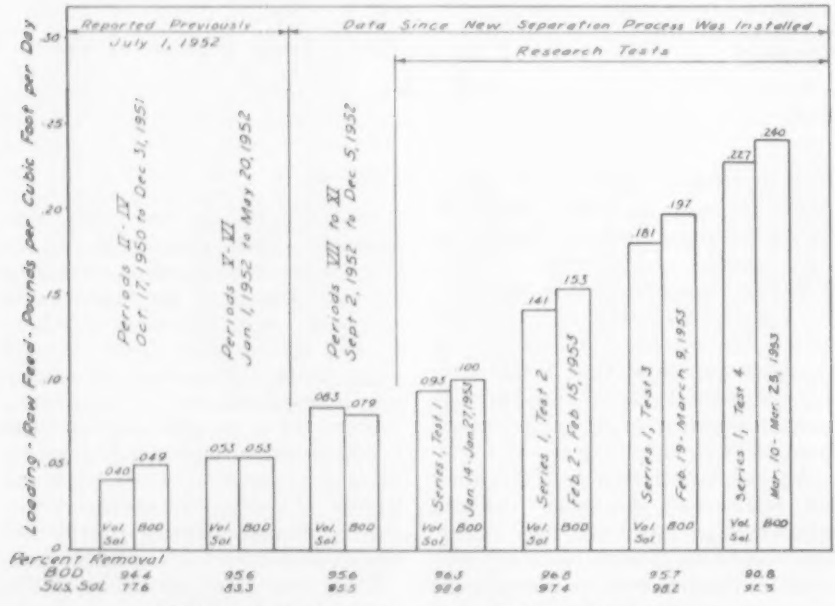
Loading - Raw Feed - Pounds per Cubic Foot per Day
Reported Previously
Data Since New Separation Process Was Installed
Research Tests
July 1, 1952
Periods II-IX Oct 17, 1950 to Dec 31, 1951
Periods X-XII Jan 1, 1952 to May 20, 1952
Periods VIII to XI Sept 2, 1952 to Dec 5, 1952
Series 1, Test 1 Jan 14 - Jan 27, 1953
Series 1, Test 2 Feb 2 - Feb 15, 1953
Series 1, Test 3 Feb 19 - March 9, 1953
Series 1, Test 4 Mar 10 - Mar 25, 1953
Vol Sol
BOD
0.40 0.49 0.53 0.53 0.83 0.79 0.95 1.00 1.41 1.53 1.81 1.97 2.27 2.40
Percent Removal
BOD 94.4 95.6 95.6 96.3 96.8 95.7 90.8
Sus. Sol 77.6 83.3 93.5 98.4 97.4 98.2 92.3

**FIGURE 4.—B.O.D. and volatile solids in various tests.**

contents increased progressively from 18.0 per day in Test 1 to 39.8 in Test 4.

The results of this series are summarized in Table I. In general, this series showed that with loadings varying from 0.10 to 0.20 lb. of B.O.D. per cubic foot per day, average B.O.D. removals of 96.3 per cent were obtained. With loadings increased to 0.24 lb., the efficiency dropped rather sharply to 90.8 per cent.

In Figures 3 and 4 the results of Series 1 are compared to the early test results. It will be seen that with detention periods in the digester (contact tank) of one-half day, removals comparable to early tests were secured when detention periods of 1.5 to 2.5 days were required. These removals were accomplished at loadings of 0.20 lb. of B.O.D. and volatile solids, whereas in the early tests loadings of 0.05 lb. were the maximum attainable. The principal reasons for the improved operation were the improvements in separation and in digester mixing.

### 1953–4 Test Program

With authorization of another year of investigation, the program of research tests recommended in the September 1952 report was begun. The test program involved four basic investigations, all conducted without the aid of fly ash, because of certain practical disadvantages inherent in the use of this additive. These investigations were as follows:

1. Tests to determine the effect of loading and detention period on efficiency to parallel Tests 1 to 4 in the previous year when fly ash was employed.

2. Tests to determine the effect of the degree of vacuum maintained on process efficiency and costs.

3. Tests to determine the effect of digestion temperature on the performance of the process.

4. A series of tests to determine the effect of degree of mixing on efficiency.

**TABLE II.—Summary of Results on Effect of Loading; Series No. 3, Tests 13–16, 19, 21, 24 and 27**

| Items | Test 13 | Test 14 | Test 15 | Test 16 | Test 19 | Test 21 | Test 24 | Test 27 |
|---|---|---|---|---|---|---|---|---|
| Volume, raw feed (cu. ft./day) | 562 | 776 | 792 | 641 | 905 | 621 | 628 | 615 |
| Volume, return sludge (cu. ft./day) | 913 | 2,893 | 2,935 | 3,041 | 2,510 | 1,770 | 1,950 | 1,610 |
| Recirc. ratio (return sludge/raw feed) | 5.18 | 3.73 | 3.70 | 4.74 | 2.77 | 2.85 | 3.11 | 2.62 |
| Vacuum (in. Hg) | 27 | 26.5 | 25.2 | 25.5 | 25.8 | 18 | 18 | 18 |
| Total vol. solids, raw (p.p.m.) | 1,511 | 1,567 | 1,560 | 1,368 | 1,375 | 1,438 | 1,470 | 1,180 |
| Total susp. solids, raw (p.p.m.) | 787 | 671 | 709 | 576 | 671 | 610 | 605 | 435 |
| 5-day B.O.D., raw (p.p.m.) | 1,100 | 1,469 | 1,565 | 1,350 | 1,470 | 1,430 | 1,400 | 960 |
| Total nitrogen, raw (p.p.m.) | 131 | 146 | 159 | 141 | 126 | 130 | 111 | 99 |
| Dig. loading, raw feed (lb./cu. ft./day): | | | | | | | | |
| 5-day B.O.D. | 0.094 | 0.175 | 0.190 | 0.142 | 0.223 | 0.164 | 0.209 | 0.144 |
| Total vol. solids | 0.130 | 0.187 | 0.189 | 0.144 | 0.212 | 0.164 | 0.219 | 0.177 |
| Total susp. solids | 0.067 | 0.080 | 0.086 | 0.061 | 0.101 | 0.070 | 0.091 | 0.066 |
| Detention period, digester (hr.): | | | | | | | | |
| Raw flow | 17.55 | 12.57 | 12.39 | 14.28 | 9.7 | 13.05 | 10.0 | 10.0 |
| Total flow | 2.84 | 2.07 | 2.63 | 2.48 | 2.58 | 3.39 | 2.44 | 2.76 |
| Detention period, separator (hr.): | | | | | | | | |
| Raw flow | 4.02 | 2.41 | 2.85 | 3.52 | 2.50 | 3.59 | 3.46 | 3.63 |
| Total flow | 0.65 | 0.62 | 0.60 | 0.61 | 0.66 | 0.93 | 0.87 | 1.00 |
| Return sludge, susp. solids (p.p.m.) | 12,360 | 13,970 | 16,670 | 14,890 | 16,350 | 14,520 | 16,200 | 17,050 |
| Return sludge, fixed solids (%) | 29.9 | 30.5 | 27.0 | 30.6 | 23.5 | 26.6 | 20.8 | 26.1 |
| Separator influent (p.p.m.): | | | | | | | | |
| Total vol. solids | 7,660 | 8,550 | 9,600 | 9,430 | 9,830 | 8,550 | 10,500 | 10,150 |
| Total susp. solids | 11,190 | 12,380 | 14,020 | 13,620 | 13,200 | 11,800 | 13,500 | 13,200 |
| Separator effluent (p.p.m.): | | | | | | | | |
| 5-day B.O.D. | 34 | 141 | 135 | 77 | 67 | 68 | 84 | 57 |
| Total vol. solids | 439 | 443 | 411 | 277 | 333 | 308 | 421 | 390 |
| Total susp. solids | 67 | 47 | 70 | 60 | 83 | 48 | 96 | 52 |
| Removal (%): | | | | | | | | |
| Total vol. solids | 71.2 | 73.0 | 73.7 | 79.8 | 74.3 | 78.6 | 71.4 | 67.0 |
| Total susp. solids | 91.5 | 93.2 | 90.1 | 90.0 | 87.6 | 91.7 | 85.3 | 88.0 |
| 5-day B.O.D. | 96.9 | 90.4 | 91.3 | 94.3 | 95.5 | 95.3 | 94.0 | 94.1 |
| Total nitrogen | 19.8 | 30.0 | 17.5 | 33.0 | 23.8 | 20.4 | 19.5 | 19.2 |
| Test period | 8/24/53 to 9/5/53 | 9/8/53 to 9/18/53 | 9/21/53 to 10/8/53 | 10/27/53 to 11/10/53 | 12/10/53 to 12/29/53 | 2/15/54 to 2/26/54 | 4/2/54 to 4/23/54 | 5/27/54 to 6/10/54 |

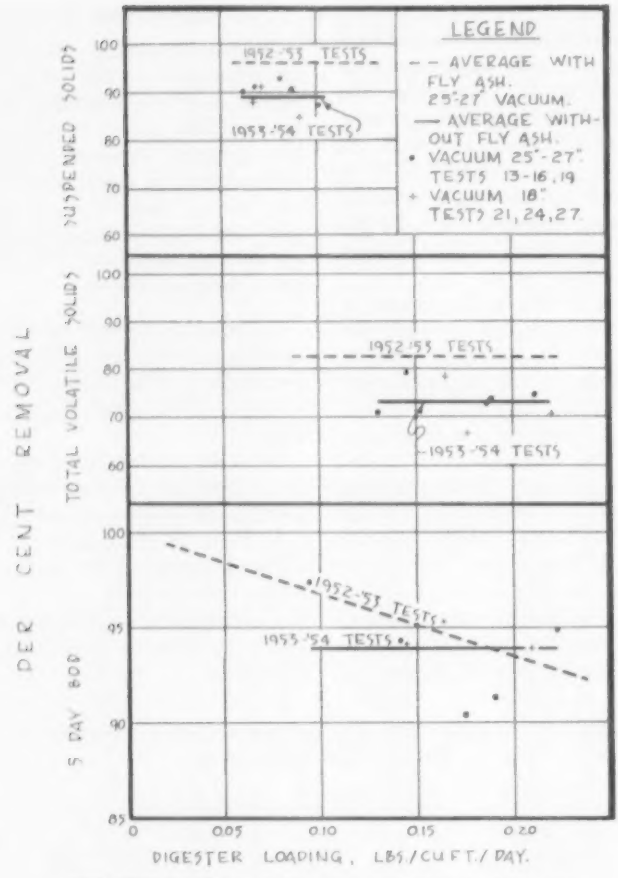


**FIGURE 5.—Effect of loading on efficiency of process.**

*Effect of Loading*

A series of tests was carried out to show the effect of loading, without benefit of additives, on process efficiency. The results (Table II and Figure 5) allow comparison with the 1952–3 efficiency tests including fly ash. The advantageous effects of the weighting additive from a theoretical standpoint are generally borne out.

*Effect of Vacuum*

Because of the importance of the degree of vacuum maintained on the costs of this portion of the process, a series of tests was conducted to determine the effect of this factor on the efficiency of the process. The economic importance of this is discussed in a later section.

Tests were conducted at vacua of 0, 10 and 18 in. of mercury, beginning in November 1953. It should be remembered that all basic research tests before this time were carried on at a vacuum of 26 to 27 in. The results of this series of tests are summarized in Table III,which does not, however, indicate the terminal results. Thus, Test 18 was terminated because solids were being lost rapidly. The same applies to Test 20. This series in-

TABLE III.—Summary of Vacuum Test Results

| Item | Test | | | | |
|---|---|---|---|---|---|
| | 17 | 18 | 20 | 21 | 19 |
| Vacuum (in. Hg) | 0 | 0 | 9.84 | 18 | 25.8 |
| Dig. loading, B.O.D. (lb./cu. ft./day) | 0.049 | 0.075 | 0.097 | 0.164 | 0.223 |
| Removal (%): | | | | | |
| B.O.D., 5-day | 93.4 | 95.0 | 92.1 | 95.3 | 94.9 |
| Susp. solids | 82.0 | 86.9 | 55.5 | 91.7 | 87.6 |
| Vol. solids, total | 67.4 | 77.4 | 59.1 | 78.6 | 74.3 |

dicates maximum loads of 0.075 and 0.100 lb. per cubic foot of digester (contact tank) at vacua of 0 and 10 in., respectively. Degassification at a vacuum of 18 in. and higher permits of higher loadings. Within the limits of maximum loading in these and later tests (see also Table II) it appears that a vacuum of 18 in. is about as effective in separation efficiency as one of 26 in., which would cost about 2½ times as much.

### *Effect of Temperature*

All of the tests reported herein are based on system temperatures of 95° F. Since thermal requirements which are discussed later are an important economic factor in the consideration of this process, a series of tests was designed to measure both the biological and physical factors involved.

The results of these tests are summarized in Table IV and Figure 6.

TABLE IV.—Summary of Results on Effect of Temperature; Series No. 5, Tests 21–23

| Item | Test 21 | Test 22 | Test 23 |
|---|---|---|---|
| Test period | 2/15–26/54 | 3/1–13/54 | 3/15–27/54 |
| Digester temperature (° F.) | 95 | 85 | 75 |
| Vacuum (in. Hg) | 18 | 18 | 18 |
| Volume, raw feed (cu. ft./day) | 621 | 630 | 635 |
| Volume, return sludge (cu. ft./day) | 1,770 | 1,680 | 1,613 |
| Raw wastes (p.p.m.): | | | |
| Total vol. solids | 1,438 | 1,310 | 1,060 |
| B.O.D., 5-day | 1,430 | 1,310 | 1,110 |
| Susp. solids | 610 | 466 | 381 |
| Dig. loading, raw feed (lb./cu. ft./day): | | | |
| Total vol. solids | 0.164 | 0.152 | 0.125 |
| B.O.D., 5-day | 0.164 | 0.152 | 0.131 |
| Detention period, digester (hr.): | | | |
| Raw flow | 13.1 | 12.9 | 12.8 |
| Total flow | 3.4 | 3.5 | 3.6 |
| Detention period, separator (hr.): | | | |
| Raw flow | 3.6 | 3.5 | 3.5 |
| Total flow | 0.9 | 1.0 | 1.0 |
| Surface settling rate (g.p.d./sq. ft.): | | | |
| Raw flow | 145 | 147 | 149 |
| Total flow | 560 | 540 | 526 |
| Return sludge (p.p.m.): | | | |
| Suspended solids | 14,520 | 17,200 | 15,900 |
| Volatile susp. solids | 10,650 | 13,150 | 12,500 |
| Separator influent (p.p.m.): | | | |
| Susp. solids | 11,800 | 13,700 | 13,000 |
| Vol. susp. solids | 8,550 | 10,310 | 10,200 |
| Volatile acids, effluent (p.p.m.) | 36 | 41 | 38 |
| No. of turnovers (digester/day): | | | |
| Mixing flow | 45 | 45 | 50 |
| Total flow, incl. ret. sl. | 50 | 50 | 50 |
| Removal (%): | | | |
| B.O.D., 5-day | 95.3 | 93.8 | 90.9 |
| Total vol. solids | 78.6 | 72.1 | 63.8 |
| Suspended solids | 91.7 | 78.4 | 58.6 |
| Total nitrogen | 20.4 | 14.3 | 13.6 |

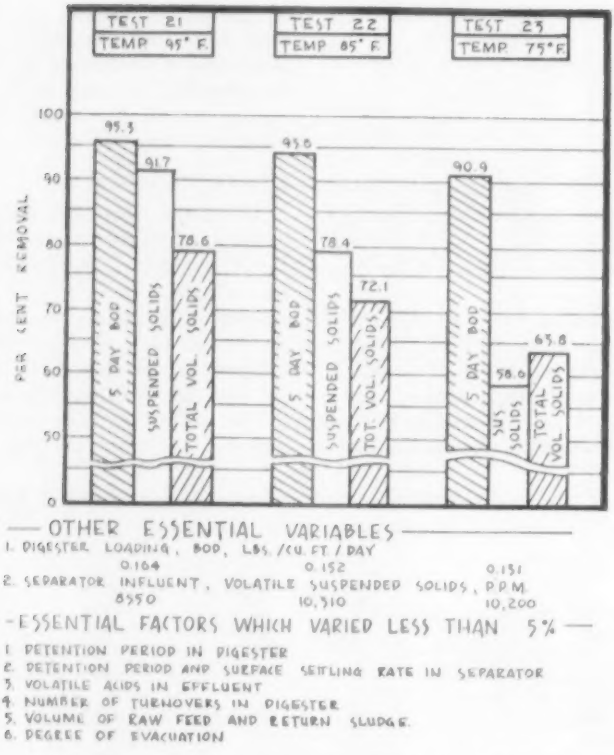


FIGURE 6.—Effect of temperature on efficiency of process.

They are further summarized in Table V, which includes also Test 5, carried on in a preliminary way between March 26 and April 11, 1953. Tests 21 to 23, inclusive, differ from earlier Test 5 in that loadings and vacua were higher, and also in the fact that Test 5 included fly ash as a weighting additive not present in Tests 21 to 23, inclusive.

TABLE V.—Summary of Temperature Test Results

| Item | Test | | | |
|---|---|---|---|---|
| | 21 | 22 | 23 | 5 |
| Digester temp. (° F.) | 95 | 85 | 75 | 88 |
| Dig. loading, B.O.D. (lb./cu. ft./day) | 0.164 | 0.152 | 0.131 | 0.216 |
| Dig. detention[1] (hr.) | 13.1 | 12.9 | 12.8 | 10.2 |
| Vol. acids, separator effl. (p.p.m.) | 36 | 41 | 38 | 110 |
| Digester turnovers (no./day) | 45 | 45 | 45 | 35.8 |
| Removal (%): | | | | |
| B.O.D., 5-day | 95.3 | 93.8 | 90.9 | 90.1 |
| Susp. solids | 91.7 | 78.4 | 58.6 | 94.0 |
| Vol. solids, total | 78.6 | 72.1 | 63.8 | 76.9 |

[1] Based on raw flow.

The tests were each of 11- to 12-day duration and were too short to draw any positive conclusions. They do suggest several important indications about which there has been some speculation and concern. The first relates to the ruggedness of the process and to what would happen if for any possible reason the temperature were to drop suddenly or materially. In this series the temperature was reduced below the control temperature of 95° for a period of 28 days without completely disrupting the process. It is true that at the end of the 75° F. test (No. 23) solids were being lost at a rapid rate as evidence by the low (58.6 per cent) suspended solids removal; it is possible that equilibrium could have been reached at a lower solids concentration, and correspondingly lower B.O.D. removal, if the test were continued.

This series also suggests the desirability of a test to determine the effect of allowing the raw waste temperatures to control the process temperature without the addition of external heat, or at least none beyond what the process produces. Temperatures might then vary in the typical plant from 70° to 75° at night to 90° to 95° during the day. Although the effluent would admittedly be somewhat inferior, subsequent treatment by trickling filters and final sedimenta-

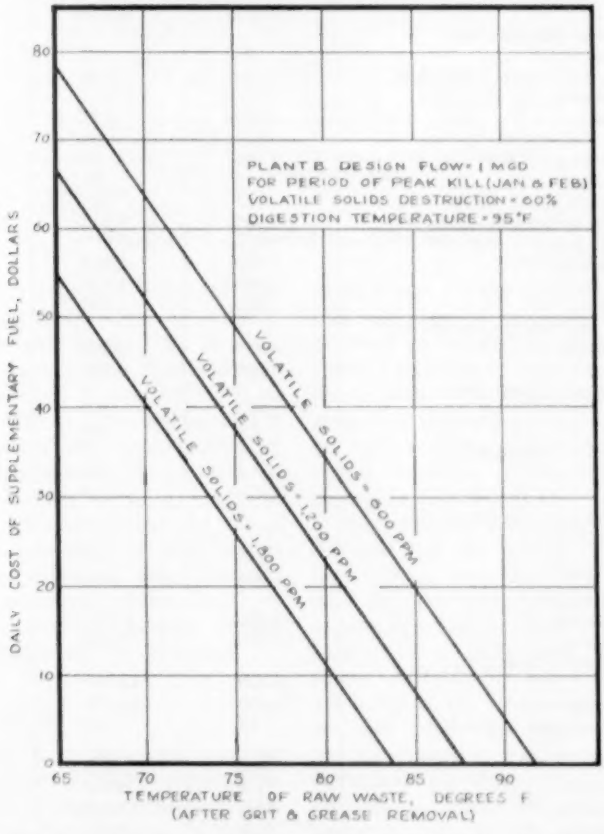


FIGURE 7.—Effect of raw waste temperature on supplementary fuel requirements.

tion to recover the solids and return them to the process, might make an over-all economical process. Land disposal (deep lagoons, oxidation ponds, or irrigation) might also be satisfactory alternatives following anaerobic treatment for reducing the total costs in special applications.

Lastly, this series suggests that a large or even a major part of the process (as in aerobic processes) may be the physical action of adsorption as contrasted with a purely biological phenomenon. This has been termed the "anaerobic contact" process, which generally describes the bio-flocculation action which occurs in the digester and continues, along with precipitation, in the separator. The fact that until a major loss of solids was experienced the B.O.D. removals were maintained, confirms this.

From an economic standpoint raw waste temperature is very important. Since practically all of the tests have been related to 95° F., this is the

**TABLE VI.—Summary of Results on Effect of Degree of Mixing; Series No. 6, Tests 24–26**

| Item | Test 24 | Test 25 | Test 26 |
|---|---|---|---|
| Test period | 4/2/54 to 4/23/54 | 4/27/54 to 5/7/54 | 5/10/54 to 5/24/54 |
| No. of turnovers (digester/day): | | | |
| Mixing flow | 58 | 31 | 12 |
| Total flow, incl. return sludge flow | 66 | 40 | 20 |
| Av. liquid velocity, dig. (ft./min.): | | | |
| Mixing flow | 1.54 | 0.77 | 0.31 |
| Total flow, incl. ret. sl. | 1.74 | 1.00 | 0.52 |
| Digester flow temp. (° F.) | 95 | 95 | 94 |
| Vacuum (in. Hg) | 18 | 18 | 18 |
| Volume raw feed (cu. ft./day) | 628 | 627 | 615 |
| Volume return sludge (cu. ft./day) | 1,950 | 2,075 | 2,025 |
| Raw wastes (p.p.m.): | | | |
| Total vol. solids | 1,470 | 1,660 | 1,430 |
| B.O.D., 5-day | 1,400 | 1,570 | 1,460 |
| Susp. solids | 605 | 700 | 595 |
| Dig. loading, raw feed (lb./cu. ft./day): | | | |
| Total vol. solids | 0.219 | 0.266 | 0.219 |
| B.O.D., 5-day | 0.209 | 0.252 | 0.223 |
| Detention period, digester (hr.): | | | |
| Raw flow | 10.0 | 9.4 | 9.8 |
| Total flow | 2.4 | 2.2 | 2.3 |
| Detention period, separator (hr.): | | | |
| Raw flow | 3.5 | 3.6 | 3.6 |
| Total flow | 0.9 | 0.8 | 0.9 |
| Surface settling rate, separator (g.p.d./sq. ft.): | | | |
| Raw flow | 147 | 147 | 144 |
| Total flow | 604 | 632 | 618 |
| Return sludge (p.p.m.): | | | |
| Suspended solids | 16,200 | 16,270 | 14,450 |
| Vol. susp. solids | 12,820 | 12,830 | 11,300 |
| Separator influent (p.p.m.): | | | |
| Susp. solids | 13,500 | 13,030 | 12,900 |
| Vol. susp. solids | 10,540 | 10,370 | 10,000 |
| Volatile acids, effluent (p.p.m.) | 47 | 45 | 124 |
| Removal (%): | | | |
| B.O.D., 5-day | 94.0 | 91.6 | 84.4 |
| Total vol. solids | 71.4 | 71.9 | 66.6 |
| Suspended solids | 85.3 | 86.2 | 81.8 |
| Total nitrogen | 19.5 | 21.4 | 21.0 |

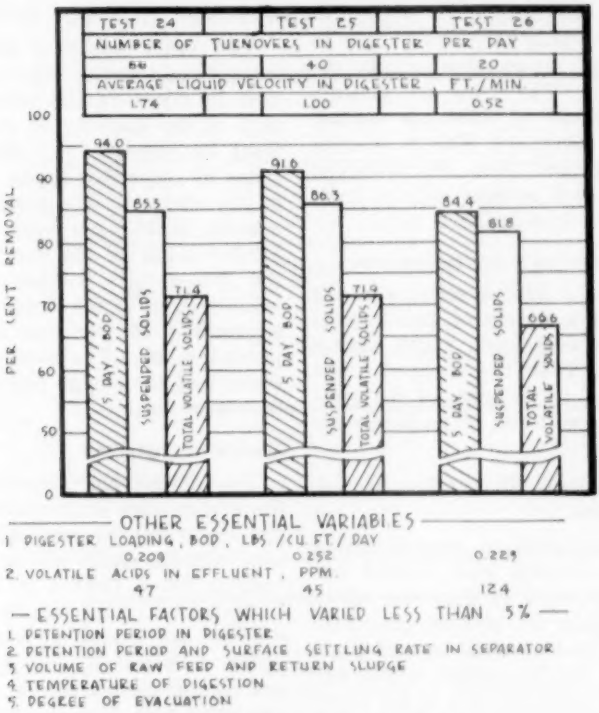


**FIGURE 8.—Effect of degree of mixing.**

datum of this report. A related factor is the concentration of volatile solids in the raw feed. This is indicated in Figure 7. Packinghouse wastes average 85° F. and 1,200 p.p.m. of volatile solids. The concentration of volatile solids and temperature of usual packinghouse wastes results in a thermal balance from a practical standpoint. The possibility of treating other wastes more or less concentrated than indicated and dilutions with other municipal wastes, involves, from a temperature balance standpoint, a study of the thermal requirements.

*Degree of Mixing*

Since this is a biological contact process, similar in many respects to the activated sludge process, it was important that the effect of "mixing" on the efficiency of the process be investigated. In the early tests mixing was not planned or controlled. Particularly at the surface of the digester, solids accumulated, out of contact with the process. The simple alteration described of impinging the mixing flow on splash plates above the digester liquid elevation accomplished a remarkable improvement.

The particular conformations of the digester and the capacity of the mixing, return, and raw feed pumps, as well as other factors, all affect an accurate appraisal of the effect of this factor on a pilot-plant scale. As shown in Table VI and Figure 8, the efficiency of the process was markedly reduced when the degree of mixing in the digester was reduced to 20 turnovers per day, corresponding to an average downward velocity of the liquid of 0.52 ft. per minute. These values cannot be considered as yard-

sticks for the design of mixing in large tanks, since they apply only to the physical set-up obtained in the pilot plant. The tests do indicate the importance of adequate contact on process efficiency. This is believed to be important from the biological standpoint, but perhaps more so from the physical flocculation action.

## Supplementary Investigations

In both the 1952–3 series and the 1953–4 tests a variety of ancillary investigations were made which have a bearing either on the economics, the performance, or the place of the process in the treatment of packinghouse wastes.

### *Effect of Raw Flow Equalization Elimination*

Two tests each of approximately two-weeks duration were carried out in different years to show the effect of equalization on process efficiency. In these tests a constant rate of loading during the 12 daytime hours was maintained at a level five to six times the nighttime loading. The tests did not simulate actual flow variations closely, but indications from these tests are that the detrimental effect of feed variations on process efficiency are small, possibly in the order of 1 to 2 per cent in B.O.D. removals.

### *Power Requirements of Evacuation System*

It was previously shown that the difference in process efficiency between an 18-in. and a 26-in. vacuum was small. The difference in power requirements, however, is of some magnitude. Measurements of evacuated gas quantity and composition permitted calculations of the power requirements at different vacua. Costs per m.g.d. of raw waste flow are as follows:

| Vacuum (in. Hg) | Power Costs, at $0.01 per Kw-hr. |
|---|---|
| 10 | $0.32 |
| 18 | $0.84 |
| 26 | $3.20 |

### *Quantities of Sludge to Disposal*

Two years' study of this question yielded an average value of 0.67 per cent in terms of the volume of raw feed as the quantity of sludge which must be disposed of. Expressed in terms of suspended solids, the pounds of dry sludge to be disposed of would amount to 16.5 per cent of the suspended solids in the raw wastes. In the 1953–4 tests without fly ash the volatile solids in the sludge to disposal constituted 76 per cent of the suspended solids. The average moisture content of the sludge disposed of was 98.4 per cent.

### *Sludge Dewatering*

The dewatering characteristics of the sludge were determined in an approximate way by small-scale tests on sand drying beds (3 sq. ft.) and vacuum filters (leaf 4 in. on a side). In spite of its high volatile and water content the sludge appeared to dewater satisfactorily on drying beds and on the vacuum filters, although in the latter type, because of the adverse effects of high volatile and moisture content, the chemical requirements were high.

### *The Separation Problem*

A variety of investigations were made of the subsidence and concentration qualities of the mixed liquor from the digestion tanks. These included hydraulic subsidence tests of particles 1 to 2 mm. in diameter, sludge index tests, measurements of the rate of lowering of the sludge-liquid interface, solids loading tests in terms of suspended solids removal per square foot per day, surface settling rates in gallons per square foot per day, etc. The limiting loading of the process apparently depends to a large extent on separation efficiency, particularly where concentrations of 15,000 p.p.m. or more of suspended solids in the separator influent result in problems of so-called "hindered" settling. In summary, the hydraulic

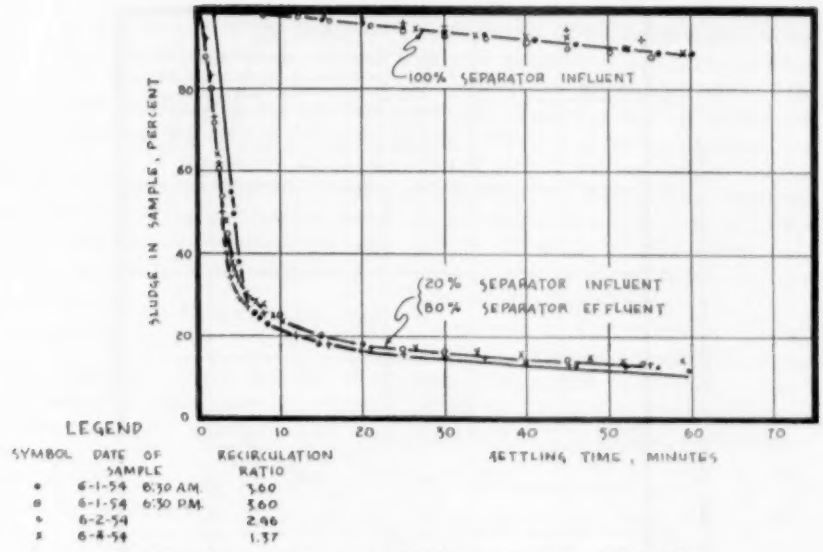


FIGURE 9.—Effect of return sludge volume on sludge index.

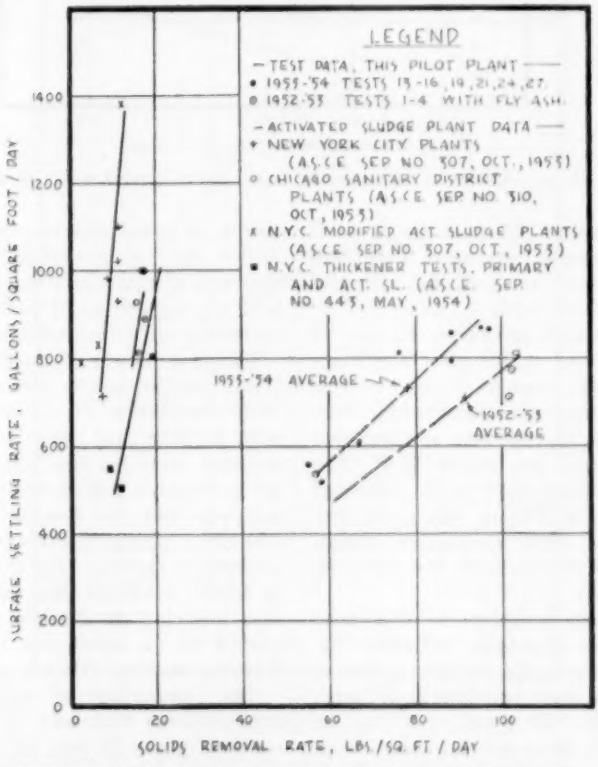


FIGURE 10.—Efficiency of separator, based on surface settling rate.

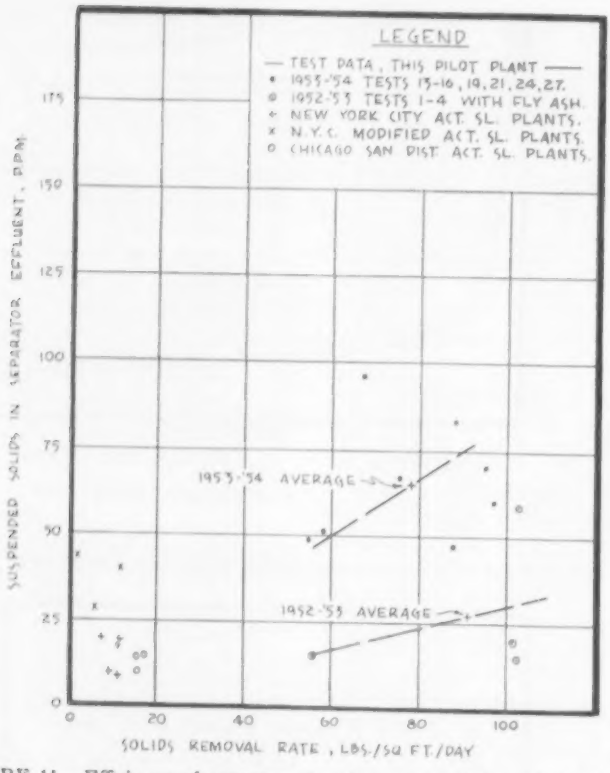


FIGURE 11.—Efficiency of separator, based on suspended solids in effluent.

subsiding values of particles 1 to 2 mm. in diameter averaged about 0.6 ft. per minute without fly ash and 2 ft. per minute with fly ash.

In tests which measured the rate of lowering of the sludge interface, average velocities (without fly ash) of 0.20 ft. per minute were measured. This corresponds to a surface settling rate of 2,150 g.p.d. per square foot. The pilot-plant separation rates indicated that values of 600 to 800 g.p.d. per square foot were reasonable design values based on the total flow entering the separator.

Under such a system as this, weir lengths and approach velocities become important. Under the conditions of the tests, weir overflow rates averaged 600 to 850 g.p.d. per foot of weir. While these are low when compared to usual practice of 10,000 to 50,000 gal., it is indicated that this factor is of real significance in dealing with the separation of particles of low hydraulic subsiding velocities.

Under a variety of operating conditions, sludge index values indicated little correlation of solids separation with loading and other factors. An average value for the Mohlman Index for a month's period was 74.5. It is believed that the basis of the index (30 min.) obscured the effect of other important factors. By the use of 4- to 6-min. readings, the rate of interface lowering on diluted samples appeared to be significant (Figure 9). Further tests on this are indicated.

The comparison of solids removal rate between this and aerobic processes (Figures 10 and 11) is interest-

ing. In Figure 10 it is indicated that suspended solids loading rates of five to ten times those permissible in aerobic processes for the same surface settling rates are possible in this process. In terms of suspended solids in the separator effluent, Figure 11 indicates that much higher removal rates are possible in the anaerobic process than in the aerobic activated processes.

### *Effect of Solids Concentration and Sludge Age*

The efficiency of the process is a combination of the behavior of the contact tank (the digester) and the separation tank. A high concentration of solids in the mixed liquor should be advantageous as far as the performance of the contact part of the process is concerned, but the problem of separation operates to reduce the over-all efficient operation in the system. The test program indicates (although this is not conclusive) that at high loadings there is an optimum concentration of about 10,000 to 11,000 p.p.m. of total volatile solids and from 13,000 to 14,000 p.p.m. of total suspended solids (Figure 12).

In terms of sludge age, as defined by Gould, Figures 13 and 14 indicate that it is possible to maintain "ages" of 10 to 17 days in this process as compared to 1 to 6 days in the various forms of the activated sludge process. The greater concentrations in the mixed liquor that have been possible

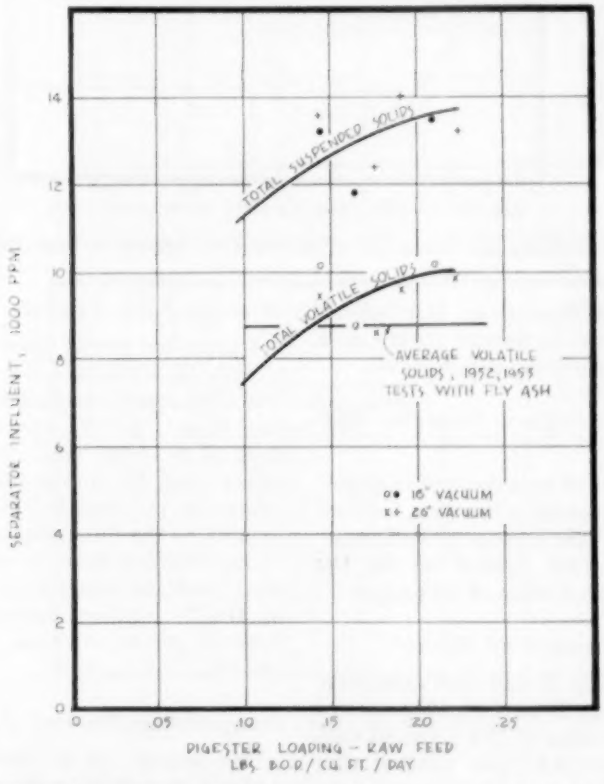


**FIGURE 12.—Effect of loading on solids concentration in digester.**

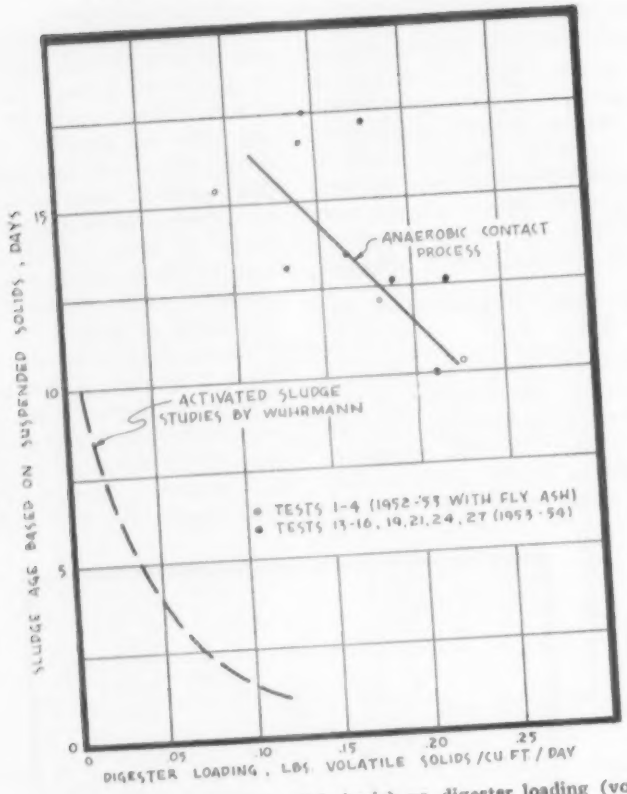


**FIGURE 13.—Sludge age (suspended solids basis) *vs.* digester loading (volatile solids).**

with degassification in this process have resulted in greater sludge ages, which have proven advantageous.

*Odor and Sulfides in Separator Effluent*

A number of tests resulted in threshhold odor numbers varying between 4 and 200. The average of 19 determinations of total sulfides for the two years yielded a value of 4.10 p.p.m.

*Chlorine Demand of Effluent*

An average of only two determinations on July 10 and 15, 1954, showed an average value of 12.5 p.p.m. of chlorine demand (0.1 p.p.m. residual after 15 min.)

*Trickling Filter Efficiency*

During the period from January 5 to June 10, 1954, the anaerobic effluent was discharged onto a pilot-scale trickling filter. B.O.D. removals ranged from 45 to 75 per cent. The tests indicate that for a well-treated waste (90 to 95 per cent B.O.D. removals) applied to the filter, the performance of the trickling filters is very close to what could be expected for the range of B.O.D. loadings applied (500 to 6,000 lb. per acre-foot per day) (Figure 15).

*Deoxygenation Constant of Effluent*

The average of 20 determinations under a variety of loading conditions

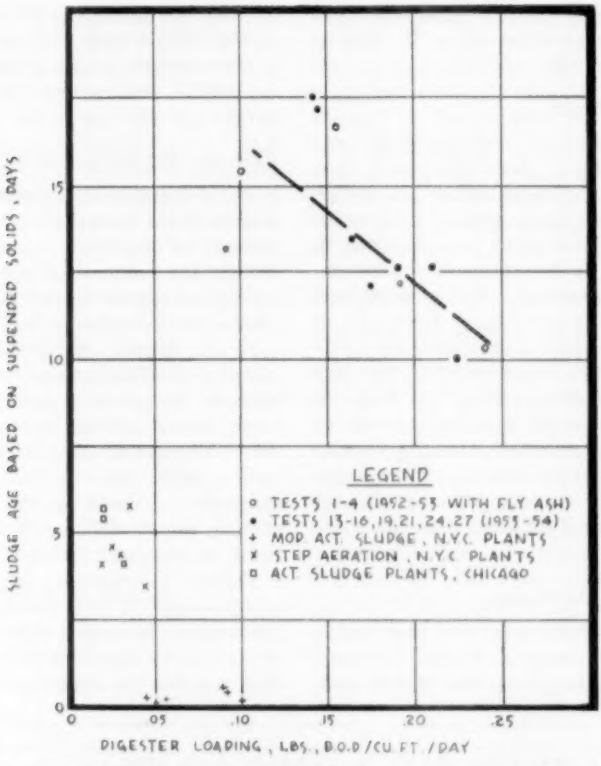


FIGURE 14.—Sludge age (suspended solids basis) *vs.* digester loading (B.O.D.).

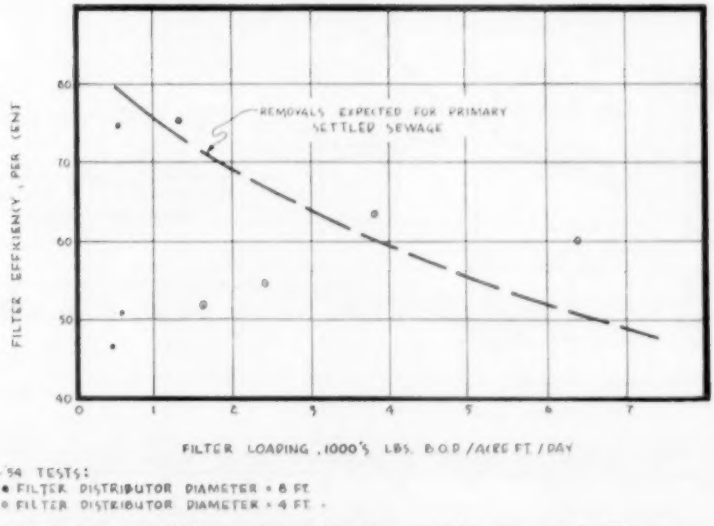


FIGURE 15.—Efficiency of trickling filter treating anaerobic effluent.

over a period of two years indicates an average $k$-value of 0.17, with a range from 0.06 to 0.26.

*Flotation Tests*

A large number of flotation tests on a laboratory scale indicated that this method of separation and solids concentration held promise. Accordingly, the pilot plant was modified in July 1954 to determine the performance of this method. Under conditions which should have been favorable to this process, high power costs for pressurizing were experienced. For the type of solids entering the flotation tank (1.4 specific gravity and up to 0.60 ft. per minute hydraulic subsiding value), the evacuation process appears to be decidedly more efficient and economical than the flotation process.

*Removal of Nutrients*

Nitrogen determinations were made daily. The removal of total nitrogen by the process during the 1952–3 tests with fly ash averaged 28.8 per cent and in the 1953–4 tests 22.5 per cent. For a three-month period from March to June 1953, the average phosphorus removal was 24.4 per cent.

*Thermal Requirements of Process*

At a digestion temperature of 95° F. significant quantities of heat are involved. Fortunately, packing plant wastes are inherently warm, usually averaging approximately 85° F. They also contain relatively high concentrations of volatile solids to furnish a gas source. The digester gas produced contains 85 per cent methane, and its gross B.t.u. content is 860 per cubic foot. The B.t.u. of the evacuated gas varies with the degree of vacuum maintained. At 18 in., the gross B.t.u. of this gas is 690, so that the gross B.t.u. of the combined gas is 830.

Figure 7 presents the results of calculations on the thermal balance for a plant having a peak daily flow of 1 m.g.d. under winter conditions with a mean air temperature of 0° F.

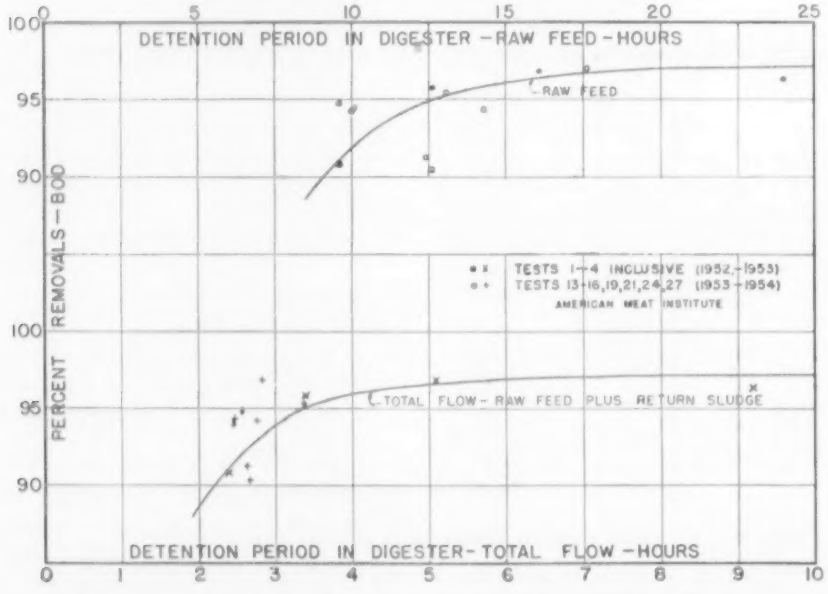


FIGURE 16.—Relation between digester detention period and B.O.D. removal.

and a ground temperature of 40° F. The figure shows that for a normal waste of 1,200 p.p.m. of volatile solids, a thermal balance exists if the raw waste temperature is 87.5°. If the raw waste is more concentrated, such as 1,800 p.p.m. of volatile solids, the balance occurs at a temperature of 83.5° F. The impracticability of the process for weak and cold sewages is indicated. Thus the cost of supplementary fuel for a waste containing 600 p.p.m. of volatile solids at a temperature of 65° F. would be prohibitive (in the neighborhood of $75 per m.g.) The foregoing calculations are based on a process temperature of 95° F. If a temperature of 85° F. were possible for a certain situation, or for portions of the year, the cost of supplementary fuel would be reduced markedly.

### *Effect of Detention Period*

It is believed that organic loading (in terms of B.O.D. or total volatile solids) is the parameter which best measures the performance of the process. With large variations in strength, the detention period in the contact tank has some bearing on efficiency. Figure 16 shows that for all of the basic tests reported for 1953–4, detention periods of 3 to 4 hr. on total flow and 12 to 15 hr. on the raw waste flow produced B.O.D. removals of 95 per cent.

## Comparison with Aerobic Processes

### *Removals on B.O.D. Basis*

While the results of this research are still on a pilot-plant scale—and, therefore, comparisons with existing operating plant data of the aerobic type may be considered premature—such comparisons are nevertheless presented so that relations with more familiar processes can be visualized.

Figure 17 is a comparison with activated sludge plants, on the basis of a parameter developed and presented by the National Research Council in their study of military installations.

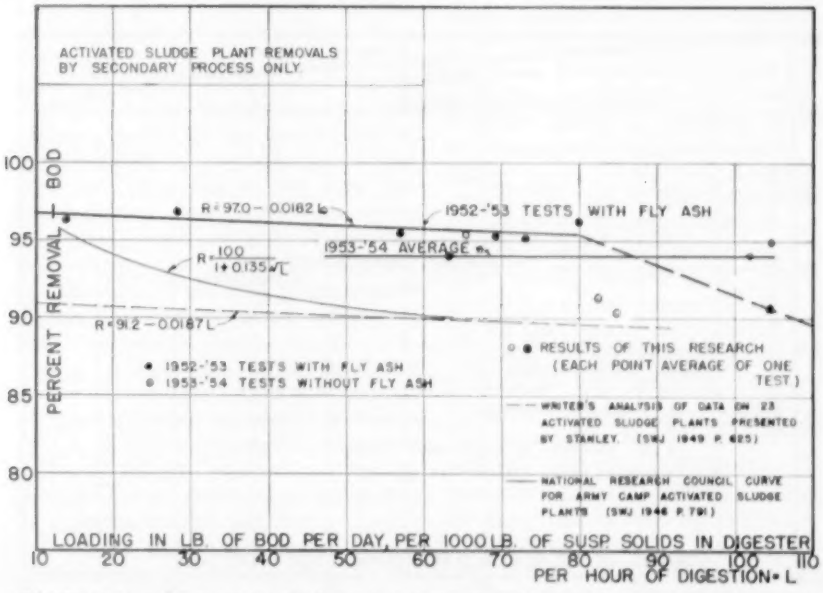
ACTIVATED SLUDGE PLANT REMOVALS BY SECONDARY PROCESS ONLY
PERCENT REMOVAL BOD
100
95
90
85
80
R=97.0 − 0.0182 L
1952-'53 TESTS WITH FLY ASH
1953-'54 AVERAGE
R = 100 / 1+0.135√L
R=91.2 − 0.0187 L
• 1952-'53 TESTS WITH FLY ASH
○ 1953-'54 TESTS WITHOUT FLY ASH
○ ● RESULTS OF THIS RESEARCH (EACH POINT AVERAGE OF ONE TEST)
WRITER'S ANALYSIS OF DATA ON 23 ACTIVATED SLUDGE PLANTS PRESENTED BY STANLEY. (SWJ 1949 P. 625)
NATIONAL RESEARCH COUNCIL CURVE FOR ARMY CAMP ACTIVATED SLUDGE PLANTS (SWJ 1946 P. 791)
LOADING IN LB. OF BOD PER DAY, PER 1000 LB. OF SUSP. SOLIDS IN DIGESTER
10 20 30 40 50 60 70 80 90 100 110
PER HOUR OF DIGESTION • L

FIGURE 17.—Comparison of effect of loading on efficiency of anaerobic contact and activated sludge processes.

Comparison is made with both military and municipal installations. Higher removals by the anaerobic process for the same loadings are indicated. If instead of the foregoing parameter the loading yardstick of pounds per cubic foot per day is employed, similar comparisons result. Top loadings in conventional activated sludge plants are almost always less than 0.05 lb. per cubic foot, which compares with possible anaerobic loadings of 0.20 lb.

A comparison with trickling filters is presented in Figure 18. The basic trickling filter relationship shown is one developed by the senior author and is quite close to a number of other curves presented by others, including the Ten State Standards. Since the anaerobic process involves sludge recirculation ratios up to 3.0, a second trickling filter curve is presented for an effluent recirculation ratio of 3.0. Figure 18 shows that trickling filters cannot approach the efficiency of the anaerobic process unless they are double- or triple-staged, and then, of course, the loadings are considerably lower. As an illustration, the loadings on the trickling filters (excluding sedimentation tanks) in the trickling filter plant designed for cost comparison in the next section amount to 0.048 lb. per cubic foot. A loading of 5,000 lb. per acre-foot per day corresponds to 0.12 lb. per cubic foot.

The difference between the efficiency of the anaerobic and aerobic process is explained partly by the higher temperatures and solids concentration that are possible in the former process.

*Comparison of Costs*

As a part of and supplemental to the pilot-scale tests, comparisons were made of the estimated costs of construction and of operation of an aerobic plant designed along conventional lines and an anaerobic plant based on the design yardsticks indicated as a result of these investigations. Plants based on peak monthly flows of 0.5 and 1.0 m.g.d. were studied.

The anaerobic contact process as

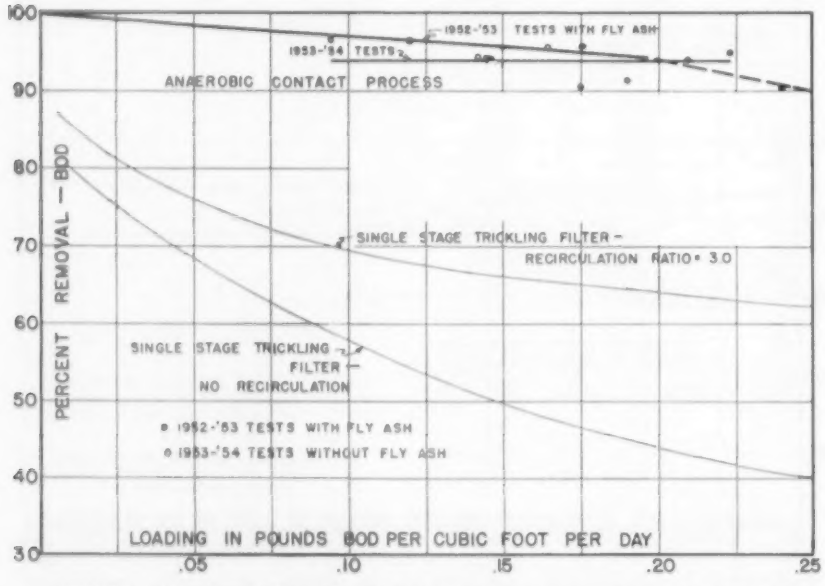


FIGURE 18.—Comparison of anaerobic contact process and trickling filters.

considered herein is remarkably akin to the conventional activated sludge process. However, because there is little information on the treatment of packinghouse wastes only by the activated sludge process, comparison has been made between an aerobic process involving two-stage filtration and the anaerobic contact process.

The following summary of costs applies to a plant designed for a peak monthly flow of 1 m.g.d. (average annual flow of 0.67 m.g.d.), to accomplish an average B.O.D. removal of 94 per cent:

| | Costs ($) | |
|---|---|---|
| | Aerobic Plant | Anaerobic Plant |
| Construction | 570,000 | 295,000 |
| Oper. and maintenance | 36,600 | 37,800 |
| Fixed charges, at 6.5% | 37,000 | 19,200 |
| Total annual charges | 73,600 | 57,000 |

## Summary and Conclusions

The research program on anaerobic treatment of packing plant wastes, which has been conducted during the past two years by the American Meat Institute at the Geo. A. Hormel & Co. plant in Austin, Minn., has contributed to a greater understanding of the actions involved in the process and to improvements in its performance and economy. Analyses of the data collected during the research tests under controlled conditions and of the records during the previous two years of operation of the pilot plant, permit of the following summary statements and conclusions:

1. A process has been developed which for this type of waste is capable of accomplishing removals in 5-day B.O.D. of 95 per cent and in suspended solids of 90 per cent at loadings up to 0.20 lb. of B.O.D. per cubic foot of digester volume per day.

2. These removals can be accomplished with detention periods in the digester of less than 12 hr. based on the raw flow, and less than 3½ hr. on the basis of total flow (raw flow plus return sludge).

3. With equal or greater removals, the process can be loaded up to four times the rate possible for conventional aerobic processes.

4. Contact between the raw waste and the biologically active sludge, measured both in time and surface area of the sludge particles, appears to be an essential of the process. The new method has been denoted as an anaerobic contact process. Reference to the method as the anaerobic activated sludge process appears to be descriptive of the actions involved.

5. The flow diagram of the process is not unlike that of the conventional activated sludge plant. The better results in the anaerobic process at higher loadings can be explained partly by the temperature advantage, and by the fact that the suspended solids in the mixed liquor can be maintained near 15,000 p.p.m., affording a much greater contact surface as compared to the 2,000 to 3,000 p.p.m. possible in the conventional activated sludge plant.

6. The process differs from other anaerobic applications by reason of the development of a method of separation employing degassification. The ability to effectively and consistently separate the solids from the liquid is shown by the fact that the influent to the separation process in all of the tests usually ranged from 12,000 to 17,000 p.p.m. of suspended solids and the effluent from 20 to 100 p.p.m., with removals of approximately 99.7 per cent. The application of these principles to ordinary sewage sludge digestion as a means of increasing capacity and reducing costs is suggested. There is a possibility that degassification may be applicable to final sedimentation in aerobic processes.

7. Preliminary estimates indicate the construction costs of the anaerobic contact process for plants of 0.5- to

1.0-m.g.d. capacity are likely to be approximately one-half of those of trickling filter plants designed to accomplish a 95 per cent B.O.D. removal on these wastes.

8. The operation and maintenance costs of the anaerobic process are estimated to be slightly greater than those of trickling filter plants.

9. The total annual charges of the anaerobic plants are estimated to be approximately 70 to 80 per cent of the cost of trickling filter plants, based on usual municipal financing.

10. The decision as between anaerobic and aerobic treatment for any particular situation involves a consideration of many local factors. Higher interest rates and property taxes with private financing are two important items.

11. A workable process has been developed which appears to be sufficiently "rugged" as to absorb the usual variations in conditions likely to be experienced in the wastes from this industry.

12. A number of possibilities for further improvement in the process suggest themselves. There are also certain questions which must be answered to assist the industry and control agencies in their acceptance of the process in its proper application.

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## ALGAE IN DISPOSAL OF RADIOACTIVE WASTES

In a brief progress report on an Atomic Energy Commission study of relationships of algae to the disposal of radioactive wastes, J. Myers and L. O. Morgan, of the University of Texas, offer the following.

Green algae, such as *Chlorella pyrenoidosa*, may accumulate inorganic ionic species from aqueous environments under appropriate conditions. To a first approximation the factors which control ionic uptake in the algae are those which are operable in the case of ion exchange in organic exchange resins. There are, however, significant deviations from typical ion exchange behavior which are probably attributable to structural factors and metabolic requirements of the algal cell.

The work was limited to typical solution species of cesium, strontium, yttrium, zirconium, and niobium, with primary emphasis on the first two. All of those elements are prominent among the fission products of uranium and plutonium and may be considered to be potential contaminants in waste streams resulting from isolation and recovery of fissionable material produced in a nuclear fission reactor. Results were observed for three essentially different accumulation processes: (a) uptake in growing algae, (b) static exchange in algae produced under optimal growth conditions, and (c) static exchange in algae produced under strictly limiting conditions with regard to inorganic nutrients.

# Stream Pollution

## LEGAL IMPLICATIONS OF STREAM POLLUTION *

By George E. Owen

*Assistant Attorney General, State of Florida*

In the United States there are two separate and distinct systems of water rights, one based on what is called the *riparian* doctrine, the other on what is called the *prior appropriation* doctrine.

From the 17 western states, which are generally considered to constitute a water shortage region, a system of prior appropriation has emerged. This emphasizes exclusive rights of use for specific quantities, times, and places, subject to the rule of reasonable beneficial use, but not depending upon ownership of land contiguous to the water supply. Here there is nearly uniform statewide administration of water development and use.

In the 31 eastern states, however, which are generally considered a water excess region but have also conditions of shortage, a system of the modified common law of water rights obtains. This emphasizes rights of water use in common without regard to specific quantities, times, and places of use, subject to the rule of reasonable use, but depending in the first instance upon ownership of land contiguous to the water supply.

Under the prior appropriation doctrine, which had its inception in the needs of the early gold miners for large quantities of water to carry on their operations, a riparian or other owner could "appropriate" the right to use as much water as he could successfully divert and beneficially use, so long as his appropriation was prior to that of others, in which case his right, on a sort of first come, first served basis, might in an extreme case extend to exhausting the flow of the stream. This doctrine, as previously stated, is used in the western states and in most cases is confirmed by legislation.

It is with the topic of riparian rights that this paper concerns itself. In order to do this, however, some definition of terms must be included. First, what is a watercourse? The cases reveal that it is not easy to define a watercourse. For the purposes of this discussion *watercourse* is considered to mean a stream of water flowing in a definite direction or course, with a channel, in a bed with banks, having a substantial degree of permanence and continuity, and all of natural origin. A *riparian proprietor* is a landowner whose land is either bounded or crossed by a watercourse. The description of his land must actually touch the water in order for him to be a riparian proprietor. This riparian proprietor has certain legal rights and privileges in connection with the watercourse which are not common to the citizens at large and which are known as *riparian rights*.

The exact origin of present day law with regard to riparian rights is rather obscure. It has been said that Story and Kent seized on the Roman Law and introduced it into American cases, and that this law then found its way into English cases. However, regardless of its birthplace, the present

* Presented at 1954 Annual Meeting, Florida Sewage and Industrial Wastes Assn.; St. Petersburg, Fla.; Nov. 8–10, 1954.

statement of the law seems to be followed in most American jurisdictions, and that is: "Each riparian proprietor is entitled to have the watercourse flow by or through his land in its natural course, quantity and quality, subject only to reasonable use of other proprietors. He, in turn, is entitled to make use of the water in the stream while on his land in any way he sees fit, provided that he does not by such use unreasonably affect the rights of an upper or lower riparian proprietor."

The nine common law states in the Southeast, including Florida, seem to follow this general rule. The first and leading Florida case which accepted and discussed this general rule was *Tampa Waterworks Co.* v. *Cline*, 37 Fla. 586, 20 So. 780 (1896). The plaintiff was a corporation which was furnishing the 8,000 or 10,000 inhabitants of Tampa at that time with water. They owned a parcel of land upon which an underground stream made a surface appearance and from there flowed to the Hillsborough River. This stream was a well-marked and defined subterranean stream coming from the east and flowing 12 to 15 ft. below the ground surface until it issued out on plaintiff's land, from whence it flowed to the river.

The plaintiff stated in his complaint that he had owned the land for 17 years; that he had made use of the stream in its pure state to serve the people of Tampa with water for their domestic purposes; that just recently the defendant acquired the lands just above the plaintiff's and proceeded to excavate to the stream and in a wanton and malicious manner was polluting the underground stream and diminishing the flow thereof; that the defendant was planning on putting up bathing pools in said stream, therefore polluting and diminishing the plaintiff's water rights; and that the defendant should be enjoined because the plaintiff needed the quality and quantity of water as was in the stream to serve the City of Tampa, which was a growing community.

In his answer, the defendant alleged ownership of his lands and denied that he was polluting and diminishing the water. He alleged that he was only making reasonable use of what was his.

The plaintiff was granted a temporary injunction, but upon final hearing his bill was dismissed.

Chief Justice Mabry, in writing the opinion on the appeal, stated at page 784:

"The mere fact that appellant has a contract with the City of Tampa to supply its inhabitants with water, and has expended large sums of money in the erection of a plant, does not confer any additional rights to the water that passes through appellee's (defendant's) land (citing cases). There is also no question presented as to the priority of right growing out of contract, prescription, or legislative grant."

Previous to this quote, the Chief Justice had pointed out that the subject of water requires four classifications which are (a) surface streams which flow in well-defined channels; (b) surface waters without well-defined channels; (c) subterranean streams which flow in well-defined channels, and (d) those which flow without well-defined channels.

At page 785, he went on to say:

"The rule as to well-defined surface streams must be applied to the stream in question. Appellee has the right to the use of this water as much as if it ran upon the surface of the ground. He cannot divert it or pollute it, but he may open up a water supply on his own land, so as not to interfere with the legal rights of adjoining owners, and also make a reasonable application of the water, certainly for domestic purposes. We discover no reasonable objection to the improvement of his own property by the removal of the soil in the depression between the rocks, over the stream, and beautifying the place by opening an accessible way to the water. The mere opening of a space, so that the rays of the sun

can reach the water below, will not of itself be a contamination or an unreasonable use of it. It is true that impurities from surface drainage might get into the stream if unprotected, and thereby pollute it, but this can be guarded against; and it is the duty of appellee to prevent the surface water from overflowing into the opening made by him. There is no sufficient showing that any serious injury has been done, or will be done with proper precaution, to the stream by reason of the opening."

Determining that the defendant was not going to build a swimming pool and was only excavating for rocks which he sold to construction companies and that these excavations in themselves did not pollute or divert the stream, as long as precautions were taken by defendant, the lower court's ruling was affirmed.

Each riparian proprietor is entitled to make use of the entire flow of a stream as he may see fit for the purpose of water power. However, he is not permitted to detain an unreasonable amount of the flow of a stream for that purpose, nor is he entitled to place obstructions in the stream which will unreasonably reduce the flow. In the case of *Price* v. *High Schools Mfg. Co.*, 64 S. E. 87 (Ga. 1909), the upper riparian proprietor maintained a dam to supply power to his cotton mill. By means of this dam he cut off the entire flow of the stream from 6 PM each night until 6 AM the next morning. This was held unreasonable as applied to a lower riparian proprietor who operated a grist mill.

One of the cardinal rights of a riparian proprietor is to have the waters of the stream come to him in their natural purity. Any pollution of the water seems to violate the rights of all lower riparian owners. The cases are in agreement that a pollution of the stream is an actionable infringement of such right. There are many cases dealing with pollution of waters, but in most of them the individual lower injured proprietors have been forced to initiate the action with little or no governmental aid. As long as municipalities constitute one of the chief classes of offenders, it will be difficult to solve the problem of pollution of streams.

## Balance of Convenience Doctrine *

Remedies which are available for the enforcement of water rights may be divided into two classes: (a) specific relief through equitable remedies; and (b) actions at law, primarily for damages. The majority of cases, however, sound in tort on the equity side of the courts, and the preferred type of relief against such torts is by way of injunction rather than action for damages. The primary reason for this preference is that injunction relief is preventive. It can furnish relief before, instead of after, a threatened violation. Moreover, in many cases involving water rights preventive relief by way of injunction may be the only effective remedy, because an action for damages will, if successful, result in such a small judgment as to be valuable only as a means of preventing the gaining of a prescriptive right by the defendants, whereas an injunction may completely stop the violation. In addition, the damages that could be obtained in an action at law can be obtained as an adjunct of the specific relief given in an injunctive suit (see *National Container Corp.* v. *State*, 138 Fla. 32, 189 So. 4).

However, there are certain limitations to the use of injunctions. These are (a) the Doctrine of Laches, where one has "slept on his rights" while the defendant acted to his prejudice; (b) the refusal of injunctive relief when the court recognizes that the injunction is being sought primarily

* Acknowledgment is made to Frank E. Maloney, Professor of Law, University of Florida, for his article "The Balance of Convenience Doctrine in the Southeastern States, Particularly as Applied to Water." 5 *S. Carolina Law Quart.* 159 (1952).

to be used as a club for the purpose of extorting an exorbitant settlement from the defendant violator; (c) the application of *de minimio* principle, under which in some jurisdictions the court may refuse to grant equitable relief when no substantial damage is alleged or proved, leaving the complainant to his action at law; and (d) the balance of convenience doctrine or balancing the equities doctrine.

The definition of the balance of convenience doctrine was best set forth in *Harrisonville* v. *U. S., Dickey Clay Mfg. Co.*, 289 U. S. 334, 53 S. Ct. 602, 77 L. ed. 1208 (1933), where Justice Brandeis stated at page 337:

"For an injunction is not a remedy which issues as of course. Where substantial redress can be afforded by the payment of money and issuance of an injunction would subject the defendant to grossly disproportionate hardship, equitable relief may be denied although the nuisance is indisputable."

In the Harrisonville case the Court held that an injunction would not issue against the discharge of an offensive effluent from a municipal sewage disposal plant into a creek flowing through complainant's farm, where the further treatment of the sewage would require a considerable expenditure for an auxiliary plant, the annual interest on the cost of which would be many times the annual loss resulting to the farmer from the nuisance, and relief could be had in money damages.

It may be worthy to note at this time, even though water rights were not an issue, the famous Ducktown Sulfur Cases in Tennessee (*Ducktown Sulphur, Copper & Iron Co.* v. *Barnes*, 60 S. W. 593 (GA. 1900)). The decisions are interesting to note and to speculate upon. Here the plaintiff was the Ducktown Sulphur Co. which was seeking injunctive relief against the prosecution of some 10 defendants suing for damages in separate suits. Damages were finally awarded the defendants, but from the facts as brought out in the case, could the defendants, had they chosen to seek injunctive relief, be successful? The Sulphur Company employed people from the community and paid monthly salaries of $17,000. The entire community was a mining community. The landowners complaining actually owned or leased small, insignificant farms. The average damage to each was less than $300. Would the court have balanced the conveniences?

Later in 1907, the State of Georgia took an interest in this Tennessee community and sought to enjoin the copper companies from discharging their noxious gases into Georgia (*Georgia* v. *Tenn. Copper Co.*, 206 U. S. 230, 51 L. ed. 1038, 27 S. Ct. 618). The State alleged that such discharges were destroying entire forest, orchard and crop lands and irreparable injuries were being done and threatened in five Georgia counties. A preliminary injunction was denied, but as there were grounds to fear that great and irreparable damage might be done, an early date was fixed for a final hearing. Justice Holmes held that if the State of Georgia adhered to its determination, there was no alternative to issuing an injunction, but only after allowing a reasonable time for the defendants to complete the structures then being built and efforts the companies were making to stop the flow of fumes and gases into Georgia.

Within nine years two more cases followed, with the court trying to avoid the issuance of a restraining decree and encouraging stipulation between the parties as to amount of damages to be paid each year and the efforts of control to be expended.

Today, the concept that the court has a discretionary power to balance the equities when determining whether to grant the injunction is again coming into its own, especially in the southeastern states.

As yet the injunction has not been widely used in the Southeast for the

protection of rights in subterranean water supplies, although the conservation of such supplies is becoming a real problem. It has been sought in many cases, however, to prevent pollution of surface waters.

In the pollution cases public interest often looms big, because the offenders are usually municipalities or large industries intimately tied in with the economy of the community. In cases of this sort one should not be too surprised to find the courts refusing to grant an injunction, the result of which would be to shut down an important industry or leave a city without means of sewage disposal. The fact that a municipality, if enjoined, might obtain a right to continue its pollution through eminent domain proceedings is, of course, a factor in some of the decisions to balance the equities; but even in the case of private parties, if the public interest in continued operation is strong enough the injunction has usually been denied. Thus, the Alabama Supreme Court in a 1952 case refused to sanction injunctive relief against pollution by a limestone company on a complaint of interference by agricultural interests (*Montgomery Limestone Co.* v. *Bearden*, 54 So. 2d 571); and there is a 1940 Florida case balancing the equities in favor of allowing a municipality to continue polluting a stream through operation of a sewage disposal plant (*City of Lakeland* v. *State*, 143 Fla. 761, 197 So. 470). However, the court in the latter case did order the City of Lakeland to take all feasible measures to cut down the amount of the pollution.

### The Florida Situation

Florida has a statute (Section 823.01) which provides for the removal of a nuisance, and Section 823.09, Florida Statutes, declares certain places to be nuisances. The leading case in Florida as to whether or not a private citizen on relation of the state could seek an injunction under these statutes is *National Container Corporation* v. *State*, 138 Fla. 32, 189 So. 4. In that case a group of citizens of Jacksonville, Fla., brought an action against the National Container Corporation, the Merritt-Chapman & Scott Corporation, and others, to prevent the use of certain lands for the erection and operation of a wood pulp mill, to restrain the drilling of certain artesian wells and to restrain the dumping of certain waste into the St. Johns River, thereby polluting the same.

The defendants filed a motion to dismiss the bill, which motion was denied. From said order an appeal was taken to the Supreme Court. Several very important questions were adjudicated in that case. The Court held (a) that in a suit by an individual in the name of the State to enjoin a nuisance, no special damage need be shown to the individual; (b) that it is common knowledge and a fact of which courts may take judicial cognizance, that all wood pulp mills emit noxious, disagreeable odors; (c) that in a suit to enjoin the erection and operation of a wood pulp mill on the theory that it would constitute a public nuisance, allegations that the mill would discharge enormous quantities of waste and refuse matter into the river and that the supply of fish in the river would be seriously reduced were sufficient to require an answer.

In that case the Supreme Court of Florida, after pointing out the statutes under which the action was filed, pointed out the reason for resorting to equity in such cases as follows:

"The nature of equitable remedy in the case of public nuisances was well described by Justice Harlan, speaking for the court in the case of *Mugler* v. *Kansas*, 123 U. S. 623, 673, 8 S. Ct. 273, 303, 31 L. Ed. 205, 214:

> 'The ground of this jurisdiction, in cases of purpresture, as well as of public nuisances, is the ability of courts of equity to give a more speedy, effectual, and permanent remedy than can be had at law. They can, not only prevent nuisances that are threatened, and before irreparable mischief ensues, but arrest or abate those in progress, and by perpetual injunction protect the public against them in the future; whereas courts of law can only reach existing nuisances, leaving future acts to be the subjects of new prosecutions or proceedings. This is a salutary jurisdiction, especially where a nuisance affects the health, morals, or safety of the community.'"

But getting to the meat of the case, the Court pointed out that the State of Florida through its citizens had adopted a constitutional amendment (Section 12 of Article 9), which provided in effect that certain industrial plants, including wood pulp manufacturing plants, were welcomed into the State of Florida and for a period of 15 years, or until 1948, would be free from taxation. While the 15-year period has now expired, the tenor of the Court's thinking at that time, and perhaps still, is given by the following excerpt from page 11, wherein the Court said:

"By the adoption of this Amendment industrial plants of the kind and character mentioned therein were not only authorized but were invited and importuned to take up their abode and operate in the State of Florida. Among such manufacturing plants are those engaged primarily in the manufacture of wood pulp, paper, paper bags, and fiber board. A statute may be effective to take a thing out of the class of public nuisance but here we have something more than a mere statute. We have provision of the organic law which is a definite recognition that a pulp mill is not a public nuisance when properly conducted and operated. It is a matter of common knowledge and, therefore, as courts may be assumed to know what everyone else knows, a fact of which courts may take judicial cognizance, that all wood pulp mills emit noxious and disagreeable odors. It may be that the volume, extent and offensiveness of such odors may be to some extent controlled and, if such can be done, it is the duty of the operators of such manufacturing plants to use the most approved and efficient methods to eliminate, as far as possible, this disagreeable feature; but, when the people of the State of Florida by an overwhelming vote, wrote into the Constitution not only the permit for pulp paper manufacturing plants to operate in this State but guaranteed to them as an inducement to come and operate in this State the exemption from all taxes certain property used in such enterprise for a period of fifteen years, it did not mean for them to come and bring their working capital and the facilities of employing hundreds of people in those plants but to leave outside the State its noises and offensive odors which would necessarily be produced when it began and continued operation.

"In other words, the State of Florida offered the inducement *cum onore*. The defendant National Container Corporation accepted the invitation and accepted the terms under the Constitution and although the odors may be disagreeable, noxious and offensive, if the plant is operated in such manner as to, as far as is possible with presently known methods, to reduce or eliminate the emission of such noxious and offensive odors, it cannot be held to constitute a public nuisance. See *Inglis* v. *Rymer*, 113 Fla. 732, 152 So. 4; *Sullivan* v. *Moreno*, 19 Fla. 200; *Randall* v. *Jacksonville Street R. Co.*, 19 Fla. 409; See also *State* v. *Erie R. Co.*, 84 N.J.L. 661, 87 A. 141, 46 L.R.A., N.S., 117; *Whitcomb* v. *Vigeant*, 240 Mass. 359, 134 N.E. 241, 19 A.L.R. 1439."

While it was held in the National Container case that the constitutional provision previously referred to immunized the container corporation from the status of a public nuisance in the operation of its plant, it did not immunize it from being held a public nuisance by reason of its of-

fending the public welfare, health and convenience by creating an obnoxious condition which by the application of known and practical methods it could obviate. In others words, the industrial plant could be required to do whatever was feasible to eliminate the obnoxious conditions.

On the question of contamination of the water, the Court at page 13 said:

"It is a matter of fact, it is a necessary part of the operation of such pulp and kraft paper mill at its particular location to discharge enormous quantities of waste and refuse matter into the River which will be highly toxic to fish and other forms of marine and aquatic life and which will be highly toxic to aquatic plant life upon which the fish are accustomed to feed and the result will be that the supply of fish in the river will be seriously reduced, if not entirely cut off, and the profitable commercial business which now exists in the catching and marketing of such fish will be seriously and permanently damaged and the facilities for pleasure and recreation will be thereby diminished and damaged. We think that it requires no citation of authority to support the assertion that the State may enjoin the consummation of the damage which is threatened even before the damaging condition comes into being."

It is believed that from this decision and others in other jurisdictions it can be deduced that the public must reasonably expect some pollution of streams, and even air, in the natural growth of the state and its communities and some of the bad must be accepted with the good. In other words, if the people expect to have large industrial plants, big payrolls, and an increase in business, the obnoxious characteristics that go with these organizations, at least to some extent, must be accepted subject, of course, to what may reasonably and feasibly be done by the industrial plant, municipality, and its sewage disposal plant, etc., toward treatment and elimination of obnoxious and injurious characteristics.

### Possible Answer to the Problem

From the reasoning of the Supreme Court of Florida in the National Container case, previously discussed, and from recent actions in Florida and South Georgia relative to the pollution of streams (public meetings to determine control features and Polk County litigation for stream pollution), the operators at Jessup, Ga., have publicly stated that they have no intention of contaminating streams. The solution seems to be on the part of all concerned a willingness to sit down at the conference table and talk the matter out and come to some conclusion that is to the best interests of all concerned, both from the standpoint of health, public welfare, and other conveniences, but within a degree that all concerned can live and prosper under the agreement. This too seems to be in line with the doctrine of balancing the equities.

Even in the Diversion and Prior Appropriation cases (principally in the western United States) there is evidence of a similar trend toward balancing the relative hardships in determining whether injunctive relief should be granted again, if the public interest intervenes, as when a municipal water supply is involved the tendency even in the western section of the country is to refuse injunctive relief and leave the complainant to his remedy at law by way of damages. But perhaps, as in the previously cited Harrison case, the courts will sometimes deny injunctive relief on the condition that damages are paid, thus guaranteeing the complaining party of damages for diminishing the value of his property.

When only private parties are involved, however, and the basic interest of the public is not apparent, the courts have been much more reluctant to consider the possibility of Balancing the Equities.

# THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

## SERVICE—CRITERION FOR OPERATOR CERTIFICATION

A prime factor in the success of a voluntary certification program is its acceptance by the municipal administrators and industrial people to whom the operators are responsible and by whom they are employed. The keynote of the program should be service to the public. Such a program has many goals, not the least of which is the ultimate elevation of operators' status to its rightful place.

The value of the program is limited by the extent that it is accepted by the public. It must be based on an attitude of tangible service rendered by sewage treatment plant personnel. Collectively and individually operators must adopt this attitude toward the certification program rather than a narrowminded "what-will-it-do-for-me" attitude.

Frequently efforts to obtain legislative approval of a licensing law meet with a notable lack of success, due principally to the failure to stress the service aspects. By using the voluntary approach it is possible to convey the idea that a free-will offering of talents is being made for the public good; in other words, "service."

The desire to provide a quality service must precede any real and lasting benefits which may be the eventual motive of any course of action. This view is opposed to some modern thinking which demands a maximum and gives a minimum.

A service viewpoint involves several aspects. There must be a conscientious desire to render service and a sincerity that will leave no doubt that service is the purpose of group or individual action. It then follows that a continuing effort to improve the service rendered must be maintained. Lastly, human nature being what it is, it is essential that the public be fully informed as to the nature and extent of the service rendered if the appreciation so essential to adequate material reward therefor is to be forthcoming. It goes without saying that a reasonably adequate material compensation is necessary to maintain the incentive for the rendering of service.

Silent service is not enough. If a service is worth doing, it is worth telling about. A technical service, such as rendered in our field and little understood by laymen, imposes an added responsibility of public education in terms and by methods that can be understood and will make clear the real value of any course of action.

The writer's experience as Chairman of the Iowa Voluntary Certification Committee has merely provided a concrete example of the complete workability of this approach. The application of this philosophy is not limited, but can provide a basis upon which to build any program or course of action. The pride of having rendered good service is in itself an intangible yet satisfying reward. The material rewards, although slower to be realized, will be more willingly and lastingly given when motivated by a real appreciation for service rendered.

H. S. SMITH, *Consulting Engineer and Guest Editorialist*

# 1954 OPERATORS' FORUM *

CARL C. LARSON, *Leader*

*Chemist, Springfield Sanitary District, Springfield, Ill.*

## Salaries and Job Classifications

*Chairman Larson:*—There is perhaps no phase of sewage treatment plant operation that is of more vital concern to operating personnel than salaries and job classifications. Regardless of whether we operate a septic tank or an activated sludge plant, we are all concerned, especially toward the end of the month, with salaries.

The Ohio Sewage and Industrial Wastes Treatment Conference has studied the subject and refers to their work as a study to promote awareness of the need for securing and retaining competent personnel in the waste treatment field.

*T. C. Schaetzle, Senior Associate Engineer, Sewage Treatment Works, Akron, Ohio:*—In 1953 the Ohio Sewage and Industrial Wastes Conference set up a committee to study the problem of salaries in the waste treatment field. Although salaries tend to be the controlling criterion, our president, a key employee in one of the large Ohio industries, suggested a study not of salaries alone, but also of means of promoting better public relations, the idea being that eventually salary adjustments would follow, thus securing and retaining competent operating personnel.

The Ohio State Department of Health has classified all sewage treatment works as either A, B, or C. Accordingly, our first step was to establish the classification of all positions normally filled at sewage treatment plants, from superintendent down to, but not including, the mechanical and labor personnel. The classification included qualifications or education, experience, and personal characteristics, together with the duties, responsibilities, and authority for each position.

The next step was a survey to secure data on plant size, flow, and population served; together with information on the actual duties, responsibilities, and salary range for each position. Questionnaires were sent out to 208 treatment facilities, but only 79 replies were received. Many different titles are used. Accordingly, the term "chief operator" was adopted to designate the individual in complete responsible charge of the treatment works.

Following receipt of the replies the plants were divided by population into small, medium, and large groups. The detailed salary ranges for operators, chemist, and supervisory personnel are shown in Table I. In many cases, especially in the larger plants, there is a step increment until the top salary is reached. For example, the salary of a chief operator may advance from $537 to $591 per month in three annual increments.

The third step was to make a comparison with the salaries paid by industry for the same classifications (Table II). The salary range suggested by Boyce and Wisely in their report on sanitary engineering salaries (see THIS JOURNAL, **25**, 1, 110; Jan., 1953) has been included for comparison. The committee has not decided on the next step to take in carrying out the program.

It is quite evident that the inadequacy of salaries offered both prospective and present employees has much to do with securing and retaining competent personnel. It should be

* From transcript, 27th Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Cincinnati, Ohio; Oct. 11–14, 1954. [The second section of the Forum (Biocatalysts) will appear in an early issue. —Ed.]

**TABLE I.—Ohio Sewage Treatment Works Monthly Salary Ranges (in $) in 1953**

| Job Classification | Population of Municipality | | | | | |
|---|---|---|---|---|---|---|
| | Under 5,000 | 5,000 to 10,000 | 10,000 to 20,000 | 20,000 to 50,000 | 50,000 to 100,000 | Over 100,000 |
| Chief operator | 140–343 | 233–395 | 300–415 | 308–390 | 325–501 | 532–701 |
| Asst. chief oper. | 210–289 | 235–374 | 280–386 | 288–350 | 400–450 | 390–555 |
| Operator | — | 219–333 | 210–320 | 242–314 | 288–385 | 327–433 |
| Supervisor of maintenance | — | — | — | 173–291 | 320–385 | 310–469 |
| Chemist | — | — | — | 310 | 320–385 | 315–469 |
| Asst. chemist | — | — | — | — | — | 320–415 |
| Chemist helper | — | — | — | — | — | 250–270 |

noted that the prospects of reasonable compensation for effort expended in public service cannot compare to that received in industry. This fact is substantiated by Boyce and Wisely, who state in their conclusions: "Existing salary schedules for public health engineers and for sewage works operation personnel are definitely below levels commensurate with the character and importance of the services being rendered. The range of management and technical salaries in the water works industry is to a substantially higher level than in the sewage field. This is undoubtedly a reflection of the greater extent of private ownership of water works." They state further, and this is important: "The implementation of salary increases in the proper quarters can best be accomplished by the Member Associations, because they are much closer to the state and municipal authorities who must take the desired action."

The question, therefore, is what can we do about it? Salary surveys have been made by the New England, Pennsylvania and California associations, and by the Indiana State Board of Health. It is not known what was accomplished by these surveys other than a compilation of data. However, I believe that a start can be made by simultaneously putting our own house in order, and conducting an educational campaign.

By putting our house in order, I mean that each chief operator must educate all his employees, down to and including the laborer, that they must produce as like employees in industry. They must be convinced that their

**TABLE II.—Salary Comparison for Ohio Municipal and Industrial Waste Treatment Plants, 1953**

| Classification | Monthly Salary Ranges ($) | | |
|---|---|---|---|
| | Ohio Sewage Treatment Works | Large Ohio Industries | Suggested for Sewage Treatment Works [1] |
| Chief operator: | | | |
| Over 100,000 pop. | 532–701 | 785–1,047 | 750–1,250 |
| 10–100,000 pop. | 300–501 | 713– 953 | 500– 750 |
| Asst. Chief Operator: | | | |
| Over 100,000 pop. | 390–555 | 713– 953 | — |
| 10–100,000 pop. | 280–450 | 649– 865 | — |
| Chief chemist: | | | |
| Over 100,000 pop. | 315–469 | 505– 656 | 500– 750 |

[1] THIS JOURNAL, 25, 1, 110 (Jan., 1953).

salary status will never improve as long as they feel they have a steady job, and can afford to take a lower salary, but do not have to work hard. This is false logic.

In addition, the chief operator should watch his budget and spend as thriftily as if he were in business for himself. It is not that sewage treatment men do not do this, but some division heads in municipal work have been known to take the attitude that more funds will be provided if they run out of money. Consequently, they are careless in their expenditures.

With plant personnel aware of their responsibilities, it becomes a problem of educating a tax-conscious public and the public officials to the need for securing and retaining competent personnel. This may take considerable time but it can be done.

The following suggestions are offered for consideration in formulating appropriate action to solve this problem:

1. Request the Board of Directors of the Federation to authorize a letter to all Member Associations recommending them to start an educational campaign in their own areas (see THIS JOURNAL, **27**, 1, 113; Jan., 1955). This is merely an enlargement of the opinion expressed by Boyce and Wisely in their report.

2. The Federation should act as a clearing house for all publicity and promotional ideas used by the Member Associations. The methods being used should be published and sent to each committee and Member Association. This information should include facts and figures on the number and value of sewage treatment works. These statistics could be used in speeches to stress the importance of this field.

3. An educational campaign should be conducted by all Member Associations, and under a time limit of two years.

4. A more or less uniform speech might be prepared for delivery before service clubs, church organizations, and other civic groups.

5. The speech could be modified for each municipality to point out the investment in the local sewage treatment works, its relation to the local pollution problem, and the qualifications required by the operating personnel to obtain the best possible effluent. The importance of the work should be stressed rather than the salaries.

6. Boards of public affairs, city councils, chambers of commerce, water pollution boards, port and harbor commissions and similar groups should receive copies of the speeches.

7. The active cooperation of the state water pollution control agencies is essential in this over-all effort.

8. A real effort should be made to obtain newspaper publicity, even to the extent of the Member Associations furnishing pictures and data needed to put such a campaign across.

In conclusion, may I emphasize that these are suggestions only. However, the answer lies an an educational campaign initiated by all Member Associations simultaneously. Such a campaign should be started immediately if we are to secure universal recognition of the professional standing of the waste treatment works operator, together with commensurate adjustments in salary.

*Mr. Larson:*—The problem of attracting and retaining competent personnel is a serious problem and Mr. Schaetzle has presented some interesting recommendations. This being an Operators' Forum places us in the rather delicate position of trying to blow our own horn. However, if we don't, I doubt if anyone else will.

*Arthur H. Niles, Commissioner of Sewage Disposal, Toledo, Ohio:*—Recently I was talking with an operator from an Ohio sewage treatment plant serving a population of about 10,000. They have never had what could be

called real publicity nor a campaign to enlist public support. The treatment plant is about 25 years old and some remodeling is being done. The local newspaper publisher was invited out. He was amazed at what he saw and proceeded to acquaint his readers with the grand job that had been done over the years, why additional improvements were needed, and why there was a need for better operating personnel. The subject of pay did not enter into the picture, but it is bound to result from this type of publicity.

I think the approach is to get publicity on the work which the individual is doing. This means that the operator must be on his toes. He has to be doing a good job or the publicity he receives will be poor and he won't get a raise. It's entirely in his own hands; all he has to do is take the initiative.

*R. F. Snyder, Sanitary Engineer, Massillon, Ohio:*—The question has come up in Massillon and other communities in Ohio regarding the attitude of cities as compared to industries in job and position evaluation and classification. Massillon is a city of approximately 35,000, and the feeling is that it is of sufficient size to justify a salary and job evaluation. It is hoped that these evaluations will be made by persons who can see all sides of the picture and put them in the right focus. Industry will evaluate their jobs according to how the job fits into the product. We are putting a service on the market and I think that we possibly will have to get out and maybe blow our own horns a little in order to convince public officials and citizens as to what is being done for the health and sanitation of our various communities. In many cases credit is not given to a man who has spent time, education, and experience in operating sewage treatment plants, because a council sets up a salary schedule and that is it.

I had the unusual experience a short time ago of losing three operators at one time. That means bringing in a man, as an operator, who knows practically nothing about the job. According to our salary schedule, with out any job evaluation, this man receives the same rate of pay as an operator who has been in the plant 15 years. If we had job evaluations and put each man in his proper classification, according to his abilities, I think it would be better for our plants, better for our communities, and better for ourselves as individuals.

Coming back to Mr. Schaetzle's remark of educating the public. Recently our Rotary Club suddenly found themselves without a speaker on a very icy day, and two hours before the meeting they asked me to pinch-hit and give them something worthwhile on sanitation. A little of that publicity got into the newspaper which was very favorable to the operation of our plant and our position in the community. As a matter of fact, it was only about two months later that our Kiwanis Club approached me in a similar manner. As a result we have been able to put sanitation and sewage treatment work before the public of our city. Since then I have spoken before a number of civic organizations that previously had no interest in sanitation and sewage treatment. Other groups came to me, not because they couldn't find someone else, but because they began to get interested. I believe it is a step in the direction we need to take to promote a better awareness of our responsibilities. Indirectly it will bring our salary schedules to a level where they are commensurate with industry and with other services of our municipalities.

*Mr. Larson:*—At Springfield (Ill.) we do not have job evaluation and I am very sorry that we don't. But you know once a precedent is established, it's very difficult to get out of the

rut. However, job evaluation certainly has a great deal to be said for it.

*R. A. Greene, Superintendent of Sewage Treatment, Jackson, Mich.:*—The City of Jackson had a job evaluation made of all employees. I think it has definitely done some good, although there are some drawbacks to it for the individual who is definitely outstanding in his job, but still is in a certain bracket. The argument is we are classifying the job not the man. Classification has helped from the standpoint of pay. The ratings were supposed to have been based on a comparison between municipal jobs and industry in the area, taking into consideration what was paid by other municipalities. The result was that salaries fell somewhere in between; they are not quite up to the industry level, but are generally a little higher than you would find in a municipality that didn't have job classification.

*Mr. Schaetzle:*—Although the starting salary often is the criterion by which a prospective employee determines his interest in a position, I would like to impress this group with the idea that we must create civic interest and respect for our field of endeavor. When this is accomplished perhaps higher salaries can be established and better employees obtained.

To illustrate the seriousness of the general inability to obtain qualified young men I would like to refer to my own organization. I am the youngest of the three key men, one of whom retires next year and another one three years from now. I must retire in five years and there is not a man in our organization who can step up into our positions—and we cannot attract them.

This condition seems to indicate the need for fostering a program whereby the status of the sewage treatment operating profession can be raised. When this is accomplished perhaps qualified men can be attracted and retained in the profession.

Another thing that comes to mind is the stigma which seems to be attached to employment at the sewage treatment works. When my daughter was young she would never say I worked at a sewage treatment works. She was ashamed of it. She always referred to it as city engineer, but when I had been in the field long enough to take up some supervisory work on the outside, she would say "My dad is a consulting engineer." This stigma needs to be overcome and I believe we can do it through the local associations with the help of our Federation.

*Clifford E. Irving, Superintendent of Sewage Treatment, Schenectady, N. Y.:*—We must look at another phase of this problem, and that is the situation where the city engineer doesn't receive the same amount of money as the operator of the sewage treatment plant. Many of the consulting engineers are running into this same problem. They are trying to hire men but can't, because the salary they want to pay them is more than that paid the City Engineer or the city official who is in a responsible position. Now, how can a situation like that be coped with and how can salaries be improved if the city engineer is underpaid?

*Mr. Larson:*—Sometimes even the city commissioner is in that position too and he resents, just a little, paying some of his employees more than he is receiving.

*Mr. Niles:*—I think a city that has a city engineer who isn't receiving as much money as the sewage treatment plant operator is of sufficient size to have a job evaluation. There are several firms specializing in this work. Also I recall that Dallas, Tex., undertook the evaluation work themselves with very little outside guidance.

Toledo paid $40,000 for a job evaluation and then the city council stepped in and messed the program up with politics. It cost the city an additional $12,000 to $15,000 to have the firm return and straighten out the mess.

The consultants made the recommendations and then set up a board to carry out the program. I am on the board and learned that you have to make it plain to the council that they cannot bring politics into the evaluation program if they expect to have one. I actually believe that the situation where the top staff is underpaid can be straightened out by a job evaluation.

*Fred G. Nelson, The Dorr Company, Los Angeles, Calif.:*—California made a job survey (see THIS JOURNAL, **25**, 8, 978; Aug., 1953) and it will be interesting to make comparisons with the Ohio survey, particularly because the California Association is trying to get certification of operators. The first attempt was to present the certification program before the California League of Municipalities. The program did not receive their approval because they branded it as simply a means of getting an increase in pay for the operators, so now the health angle is being stressed.

*Bernal H. Swab, Consulting Engineer, Oklahoma City, Okla.:*—Consulting engineers can help or deter the status and salaries of operating personnel. Engineering reports for construction work include an item for operating expenses and the tendency is to keep this to a minimum. The engineer can use a little optimism and be realistic about his operating costs. In doing so he can help a lot.

*Mr. Larson:*—That's fine in the case of new plants, but I am not sure that it would be for existing plants.

*W. C. Tims, Superintendent of Sewage Treatment, Tampa, Fla.:*—Florida has been growing rapidly and heretofore there have not been many operating personnel. Accordingly they had to be trained and efforts are being made to improve the salaries by various and sundry methods. One method is to bring the sewage plants to the attention of the city fathers. In doing this the city officials have been invited to the plant, and as a result a number of discrepancies and misunderstandings have been ironed out.

Close cooperation is maintained with the Florida State Board of Health and the voluntary certification program of the Florida Water and Sewage Works Operators Association. Our civil service commission has recognized these certificates. An operator receives a raise ranging from $15 to $52.50 per month each time he passes one of these examinations. However, when a young engineer comes to work he starts at the bottom. A junior operator starts there too, regardless of how much education or experience he has. We maintain good relations and we have evaluated the salaries to the best of our ability at this time. The plant is only three years old, but it is hoped to continue to improve our public relations. Talks are now being made to the Kiwanis Club and similar groups.

*Mr. Schaetzle:* I wonder what has been accomplished by the salary surveys in New England, Pennsylvania, and California, and by the Indiana State Board of Health, other than the securing of a considerable amount of statistical data? I am afraid that is what the Ohio survey will amount to if it is not followed up with something along the educational campaign line.

*William E. Ross, Superintendent, Richmond (Ind.) Sanitary District:*—I can't speak for the Indiana State Board of Health, but the salary situation in Indiana is peculiar in that the state legislature sets the salaries for the mayors, city council members, city engineers, and other municipal officials and employees, except the sanitary districts. The police and firemen have wonderful and rather potent organizations that go to the state legislature and get a raise almost annually. The raise can be enforced because it is a state statute. The city

engineers are usually turned down and the sanitary district people aren't even in the picture.

Another thing confronting sewage plant operators is that as far as the taxpayer is concerned it's all outgo. In Richmond the municipal electric plant is considered by the taxpayer as a wonderful utility because it makes money. Accordingly, the employees have no difficulty obtaining a raise. The Sanitary District, on the other hand, operates on a separate tax and spends all the money that the water and light plants earn. It takes a good deal of public relations and favorable publicity to counteract a situation like that.

When you are in the position of getting as much as the mayor, or maybe more, and you receive almost double the city engineer's salary, you are up on the chopping block. Uneasy is the head that wears the crown. This is a situation that has to be corrected on the state level before much can be done on the local level.

Right now everyone is home-rule conscious and every time operator certification is proposed there is the accusation of infringement on home rule. Some very worthwhile legislation presented is knocked out because of this feeling. It is difficult in Indiana, even after the surveys are made, to convince the people that the data thus obtained ought to be used. Job evaluation doesn't mean too much as long as the key positions are governed by state statutes.

*Sol Seid, Supervisor of Public Works, New Brunswick, N. J.*:—The New Jersey Sewage and Industrial Wastes Association has done much for the operational field in that state. About five years ago the association decided that the officers should visit each of the three sections in the state. The state association is divided into north, south, and central sections. Each section meets several times a year and either the association president or a vice-president attends.

The sections were advised to invite the municipal officials to their meetings. The theme of the talks to these sections has been on bettering the position of the operators. Salaries in the State of New Jersey have been raised considerably in recent years through the efforts of the association. I agree that if each local association will spend a little more time with their members and will make the effort to impress upon the public officials that the sewage field is no different than the water field, the salaries will be comparable to those of the waterworks men in their communities. In many communities the salary of the water plant superintendent is far above that of the sewage plant superintendent. I think that is due to poor publicity and poor public relations on the part of the sewage works profession.

TENTH EDITION OF "STANDARD METHODS" AVAILABLE

Members of any of the three collaborating organizations that jointly prepared the publication may obtain the Tenth Edition of "Standard Methods for the Examination of Water, Sewage and Industrial Wastes" at a special price of $6.50, provided remittance accompanies the order. Otherwise the regular price of $7.50 will obtain for the 522-page volume.

See front inside cover of this issue for details.

# PLANT BEAUTIFICATION

By George T. Lohmeyer

*Superintendent, University of Florida Sewage Treatment Plant, Gainesville, Fla.*

Of all the sewage treatment plant nuisance complaints received by a state regulatory authority, a majority of the grievances were directed at treatment plants whose operational staffs failed to maintain the plant grounds in a satisfactory condition. The reason for this feeling, whether psychological or physiological, is not important. What is important, it appears, is that sewage treatment facilities with well-manicured exteriors receive fewer complaints. Slip-shod grounds may indicate slip-shod operation.

## Beautification is Essential

A luxuriant green lawn around any building, private or public, enhances the appearance tremendously. However, appearance is not the only advantage. A well-kept lawn keeps summer temperatures lower in a building and prevents wind-blown dust from entering outside equipment. It has been said that the first impression is made through the sense of sight. Therefore, it behooves every operator who wishes to impress the public and the city officials not to neglect this essential phase of operation. Furthermore, every operator should do his utmost to improve his working conditions. An excellent beginning is on beautification of the site.

A dollar-wise developer in one of the Southern states recently completed an urban district which included complete water and sewage facilities. Special emphasis was placed on landscaping the grounds of the facilities. This man, with many years of business experience, recognized that money so spent was wisely spent. Similarly, money spent on beautifying municipal sewage treatment plants is well used.

Fortunately, the trend today is to include landscaping in the initial construction cost of the project. This trend is wise, since the operator who assumes the responsibility of operating a new sewage treatment plant generally has his hands full during the shake-down operation period with the "shennanigans" of things mechanical.

## Dressing Up an Old Plant

On the other hand, if an operator has inherited an old treatment plant with inadequate grass, shrubs, and trees, the only place to commence a landscaping project is to establish a well-graded ground surface, with special attention directed to obtaining proper drainage. Only grasses suitable to the local region should be planted. Sewage treatment plant operators are encouraged to cooperate with their "up-the-line" brothers at water plants in furnishing pulverized digested sludge for lawn application. It is important that sludge be used in thin applications rather than too thick. Frequent applications are better than one heavy dose. It is usually advisable to schedule sludge applications for cooler weather, particularly in the warmer Southern states. Complete sewage treatment plants producing a satisfactory secondary effluent have the advantage of possessing a highly effective lawn sprinkling agent —the chlorinated effluent; that is, if conditions permit its use. Best results are obtained by sprinkling for a minimum of 4 hr. during the night when evaporation losses are at a minimum.

## The Bare Minimum

The extent to which an operator can landscape his grounds depends on the location, type, and operation budget

of the sewage treatment plant. Certainly, every treatment plant should have the bare minimum—a well-graded, grassed lawn. In addition, every plant in a conspicuous location should have the additional minimum requirement of judicious planting of shrubbery, for plants are the "press agents" of the profession.

### Tips on Shrubbery

In arranging landscaping, care should be taken that elaborate plantings are not made. They require many hours of extra "hand" labor. If possible, visualize how plantings will look. How would a bed of petunias look in the center of a wide expanse of lawn? Operators should not over-expand their landscaping beyond the means of maintenance. Hedges are beautiful, but be sure that someone will have the time to keep them trimmed properly at all times. Well-placed shrubbery can do much to improve appearance. The order of planting shrubbery is first at the outside corner of the control building and then along the entrance walks, followed by plantings along the walls. Shrubbery can be used advantageously to hide the contents of a tank from the eyes of casual plant visitors. Likewise, ugly pipes and unsightly low buildings can be partially or completely obscured as required. No essential line of sight should be blocked by shrubbery.

### Use of Trees

Trees can be added as landscaping progresses. Fancy or ornamental varieties are not required. Native trees should be used, because they grow better, require less attention, and do not give the impression that an attempt is being made to develop a botanical garden. Generally, trees look better planted around the perimeter of the sewage treatment plant grounds, but an existing tree elsewhere should not be sacrificed in order to follow this rule. Trees should never be planted so that leaves and roots cause operation problems in tanks or sludge beds. They should not be planted in a site designated for future expansion.

### Beautification Not Impossible

The cost of landscaping grounds is always the first objection raised. It has been found that the expenditure of even a fraction of 1 per cent of the total construction cost will provide considerable improvement in the appearance of any treatment plant. The biggest factor is the attitude of the operator. Some sewage treatment plant operators have obtained a number of shrubs by bartering digested sludge with local nurseries; another operator enlisted the support of a local women's garden club in beautifying the treatment plant; still another operator completely sprigged his grounds by using an extension light and working at night. Perhaps the old maxim: "Where there is a will, there is a way," is the key to successful projects of this nature.

### Available Bulletins

The agriculture experiment stations and extension services of the state universities publish a number of bulletins on shrubbery, perennial flowers, grasses, and other plants that do well in the particular state. This material will greatly assist the operator in his beautification plans. Often the county farm agent can be of great help with tips on plants and their care.

Developing a beautiful landscaping cannot be accomplished in a day, week, or month. It is a long-range proposition for all the operators in a sewage treatment plant. One thing is certain, a beautifully maintained treatment plant will soon reflect in the morale of the operator and inevitably in the quality of operation.

# INTERESTING EXTRACTS FROM OPERATION REPORTS

"The biggest mistake is the fear that you will make one."—*Anon.*

*Attention operators!* It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, 4435 Wisconsin Ave., N.W., Washington 16, D. C.

## 22nd Annual Operation Report of the DeKalb (Ill.) Sanitary District Sewage Treatment Plant, for the Year 1953 *

By Donald E. Henn, *Manager*

### *General*

The year was rather eventful, with several equipment failures and difficulty in maintaining normal operation of the treatment units. Equipment failures were due to normal wear and age, while the operating trouble occurred with a known overloaded sludge digester. Nevertheless, the plant was kept in continuous operation and sewage was not by-passed.

Sanitary sewers and a lift station for a 90-acre residential development were formally annexed to the District. This was the first annnexation since formation of the district and brings the total area served to 2,890 acres.

The year was the driest of the 19 years in which rainfall records have been kept. As a result, the sewage flow was low and accompanied by an increase in the quantity of suspended solids and B.O.D. handled by the treatment units. Treatment efficiency was slightly better, however, than the preceding year.

No difficulty was experienced in handling canning wastes and no fish kills occurred in the DeKalb branch of the Kishwaukee River.

### *Plant Units*

The plant units operated on much the same basis as during the preceding year. Motor failure on the raking mechanism required the replacement of the electrical connectors. Grit basins operated with a minimum of attention.

The primary clarifier scrapper mechanism was in continuous operation except for a brief period to replace the sliding electrical contacts and the magnetic control switch. Suspended solids efficiency averaged 58.1 per cent removal.

The fixed nozzle trickling filter operated without rock spalling, underdrain clogging, or ponding. Winter covers were removed from the dosing tank in April and replaced in November.

As usual, the secondary clarifier was by-passed for the winter, when the slough from the filters is slight. The sludge pump caused considerable trouble throughout the year, finally resulting in a complete overhaul, which put the clarifier out of service for seven weeks when it was needed the most.

### *Digestion*

Except for a plugged sludge discharge line, which was opened with the aid of a stream from high-pressure fire hose, the digester operated without serious difficulty until mid-November. At that time a combination of circumstances resulted in the filling of the digester with raw sludge with very little

* For last previous extract see This Journal, **26**, 1, 103 (Jan., 1954).

seed sludge available. The capacity of the digester had been reached several years before and only by judicial use of it and two sludge storage tanks, plus drying beds and lagoons, was it possible to handle the solids load.

During the summer, when cannery waste was being treated, digested sludge had been drawn to make room for raw sludge. In October the cannery appealed to the district to take some of the lagooned waste because wind and wave action was causing damage to the lagoon banks. The waste was released to the district sewers at a low rate. Due to the low sewage flow a high percentage of solids settled in the primary tank and were pumped to the digester. In addition, the filters also unloaded, adding to the solids load.

As a result the digester was full of sludge early in November. Sludge was removed from the bottom of the tank as raw sludge was pumped in at the top. Usual operating practice is to pump sludge from the digester into one of two sludge storage and conditioning tanks. On November 16 two beds of sludge were drawn and found to be undigested. No further sludge was drawn to the beds, but sludge was still pumped to the storage tanks.

Gas production fell steadily from 9,000 cu. ft. to 4,600 cu. ft. per day. On December 2, two of the five burners in the gas-fired boiler were converted to the use of propane gas. By December 10 gas production was down to 1,650 cu. ft. per day and the digester pH was 6.0 at a temperature of 80° F. After resting the digester two days, sludge was added once a day in small amounts. On December 15, 2,800 gal. of digesting sludge were hauled from a neighboring plant as seed. Air temperature dropped to the low for the year, − 7° F. Gas production slowly increased from the low on December 10 until by December 19 the use of bottled gas was discontinued. By the end of December the pH was approaching 7.0, with rapid digestion taking place. Gas production was 15,500 cu. ft. per day on the last day of the year.

Ample gas was produced for all needs except between December 2 and December 19. This was the first time auxiliary fuel had to be purchased in the 24 years of plant operation. There are no gas storage facilities available.

*Sludge*

Early in December partially digested sludge was pumped from the storage tanks to the lagoon. Sludge was dried on the drying beds from late March until mid-November. All sludge stockpiled in 1953 was delivered in the fall, and very little will be available for spring 1954 delivery. Although the local country club would have contracted for the entire supply, their offer was rejected to save the sludge for district property owners who were establishing lawns.

*Plant Grounds*

The sewage treatment plant is known locally as the place where beautiful gladiolas are grown, and in the summer the asters produce a fine array of bloom. Lawn care included the construction of a new lawn at one of the pumping stations and 17 mowings of the 4-acre plant grounds. The small greenhouse continued to be a source of pleasure and assisted in starting seedlings.

*Sewers and Pumping Stations*

Sewers were constructed in the two new subdivisions and plans were completed for a third addition. No sewer failures occurred during the year and all dead ends were flushed. Routine maintenance included the flushing and cleaning of laterals requiring attention.

The district's two wet well pump stations were inspected daily and all pump motors were cleaned and serviced. Due to a pump failure and sub-

sequent clogging of the second pump, one station was out of operation for 24 hr., with some overflow of raw sewage. The pneumatic ejector pumping station serving a small subdivision was serviced once a week.

*Canning Waste*

Cannery waste was discharged in a predetermined amount, depending on the crop being packed and the capacity of the treatment facilities to handle the load. Waste in excess of the amount discharged to the sanitary sewer was pumped to a lagoon after the addition of sodium nitrate. The lagooned waste was drained to the sanitary sewer during the spring so that the lagoon was empty at the start of the next year's pack. Due to the heavy pack during the 1953 season the lagoon was full at the end of the season and some waste was drained to the sanitary sewer.

Handling of the cannery waste followed the normal pattern of previous years, with no operating difficulties except as the solids load affected the digester.

A brief summary of 1953 operating data is given in Table I.

TABLE I.—Summary of 1953 Operation Data, DeKalb (Ill.) Sanitary District

| Item | Average | Item | Average |
|---|---|---|---|
| Rainfall, total (in.) | 24.26 | Final | 60 |
| Tributary population | 14,000 | Reduction (%) | 72 |
| Sewage flow (m.g.d.): | | B.O.D. (p.p.m.): | |
| Average | 1.45 | Raw | 239 |
| Maximum | 1.96 | Settled | 135 |
| Minimum | 0.94 | Filtered | 53 |
| Screenings (cu. ft./m.g.) | 2.0 | Final | 49 |
| Sludge pumped (1,000 gal./day) | 3.76 | Reduction (%) | 70 |
| Suspended solids (p.p.m.): | | Dig. gas produced: | |
| Raw | 219 | (1,000 cu. ft./day): | 10.5 |
| Settled | 89 | (cu. ft./cap./day) | 0.75 |
| Filtered | 69 | (cu. ft./m.g. sewage) | 7,382 |

# OPERATION AND MAINTENANCE OF SEWAGE PUMPS *

By George Strudgeon

*Assistant Sanitary Engineer, Chicago Pump Company, Chicago, Ill.*

Pumps are the heart of the modern sewage treatment plant. Without their faithful operation treatment facilities large or small, simple or complex, would soon be uninhabitable. In order to keep this heart pumping, an effective protective maintenance program must be carried on. It does little good to start a program after a major breakdown occurs. Operating personnel must know at all times the condition of the plant equipment and immediately correct weaknesses.

Proper care and maintenance means good housekeeping. It is easier to keep equipment clean and in repair than it is to make emergency repairs when everything is covered with grease, dirt, or sludge and the various parts are rusted together.

A program of regular maintenance should be set up. One of the easiest ways to do this is to make a chart or

* Presented at 3rd Annual Meeting, Nebraska Sewage and Industrial Wastes Assn.; McCook, Nebr.; Nov. 11–12, 1954.

card file showing the required maintenance operations, with a place provided to check off each item when the work is done. This chart will provide a method of reminding the responsible party when oiling, greasing and inspecting should be done, and will also provide a record of the maintenance work.

The operator should familiarize himself with the working of each piece of equipment in the plant. This can be done by studying the operation literature supplied by the equipment manufacturer. If this literature cannot be located, the operator should write for it. These booklets will also form a basis for making the maintenance chart for the plant. Cuts and drawings of the various pieces of equipment should be kept on file for reference. This material also can be obtained from the manufacturer. A drawing showing the location of all underground structures and pipe work should be kept on file for ready reference in case of trouble.

## Pump Lubrication

Nothing will cripple the sewage treatment plant more quickly than a breakdown of pumping equipment. Complete understanding of pump construction and function, together with periodic inspection and repair, are essential to avoid breakdowns.

A sound maintenance program for pumps and pertinent accessories should be developed, and a regular inspection schedule adopted based on actual operating experience. To insure the best operation and care of pumps, weekly inspection and maintenance should be made of the following:

1. Bearings, for heat and noise.
2. Motors, for starting and operating speed.
3. Control equipment, for cleanliness and condition.
4. Pump operation, for vibration and noise.
5. Packing glands, for excessive leakage.

Examination of a centrifugal pump reveals that it consists essentially of only one moving part, an impeller rotating in a casing. The impeller is supported on a shaft, which is in turn supported by a thrust bearing and one guide bearing. Vertical dry pit and horizontal type pumps require one guide bearing, whereas submerged type pumps require two or more bearings, depending on the depth of the wet well.

Vertical dry pit type pumps are constructed almost exactly the same as horizontal pumps. The bearings are generally of the ball type. Scru-peller pumps are fundamentally the same as horizontal centrifugal pumps, except that a stellited screw, cutting bars, and cutting ring are mounted on the suction side of the impeller for cutting up the solids before they reach the impeller.

Submerged type pumps are constructed differently from centrifugal pumps. The thrust bearing is of ball bearing construction and generally is located above the motor floor level where it will be free from floor drainage and sweepings. The pump casing, guide bearings, and shafting are extended into the wet well. Ball bearings cannot be used for guide or intermediate bearings because there is no effective means for sealing the bearings from the sewage, which would cause corrosion and rust. For this reason, submerged type pumps usually are built with sleeve type guide bearings of bronze.

### *Packing*

One particular packing cannot be recommended for all uses. The type of packing that should be used will depend on the operator and variations in operating methods, conditions, and requirements.

Metallic and semi-metallic types of packing, together with graphite-im-

pregnated soft asbestos, and leather, are commonly used in sewage pumps.

Soft asbestos impregnated with graphite is the most generally used packing, particularly in centrifugal and plunger type pumps. It definitely should be used where grease or water seals are not provided. On the other hand, metallic or semi-metallic packing should be used only where water or grease seals are used.

Packing containing rubber generally is not recommended because rubber has a tendency to swell when in contact with sewage.

Lubrication of the packing increases pump efficiency and reduces friction to a minimum, prolongs the packing life, and controls leakage without undue gland pressure. Where grease lubricants are used a generous quantity should be applied when the packing is installed. Thereafter, the lubricant can be applied by a hand pressure grease gun. The ideal way is to use a forced feed lubricator, applying a small but continuous amount of grease at a constant pressure.

Since the packing in the stuffing box rubs against the shaft, it is just as important that it be lubricated as the bearings. In pumps handling dirty water, the packing is lubricated the same as the bearings. In pumps handling clear water, the packing is lubricated internally with the water pumped. However sewage contains grit and, therefore, cannot be used for lubrication.

Grease is used but seldom with complete success, because some grit invariably works back into the grease, imbeds in the packing, and forms a fine abrasive cloth, which soon wears out the packing and shaft sleeve. An external supply of water for the seal is the most effective lubricant.

If a grease seal is used, and the pump head does not exceed about 20 ft., it should be fitted with a spring-loaded pressure type grease cup. Grease should be forced through the packing daily at a rate of 1 oz. per day. If the head is greater than 20 ft., spring-loaded pressure grease cups are not very effective. In such cases, a hand type grease gun should be used and the grease should be applied daily.

If a water seal is used the pressure should be greater than the operating head of the pump. This pressure may be secured by a float controlled tank, located at the highest point of the building, or with the aid of a small pump. Seal water should never be obtained by a direct connection with a drinking-water supply, because of the danger of cross connections.

The life of the packing and shaft sleeve depend almost entirely upon the effectiveness of the grease or water seal. There should be a slight leakage of water from the packing box when the pump is running, to keep the packing cool.

A packing gland should never be tightened more than necessary. Finger-tight should be ample; otherwise excessive pressure will cause the shaft sleeve to wear rapidly and the tight packing will act as a brake band, resulting in higher power consumption.

If the stuffing box leaks excessively, remove the packing and examine the shaft sleeve. If the shaft sleeve is badly grooved or scored, it should be replaced or repaired immediately. Otherwise, the stuffing box will continue to leak excessively and regardless of how it is repacked, the packing life will be short.

When the packing becomes worn remove it entirely and thoroughly clean out the stuffing box. It is bad practice to use part new and part old packing. When repacking it is important that the first two layers are properly in place, before more is added. If this is not done, the bottom layer may be forced in unevenly and may leave a pocket to collect grit. Packing should be installed with butt joints staggered around the shaft.

### Wet Wells

The size and shape of the wet well bottom are very important. If it is too flat or too large, solids will collect in the bottom and become septic. This condition may cause the presence of objectionable odors, increase soluble B.O.D., or upset the treatment plant process.

The purpose of the wet well is not to store sewage, but to provide a suction well for the pumps. Some wet wells make excellent primary tanks and defeat their original purpose.

In many cases, wet wells, which are entirely too large and function as septic tanks or primary tanks instead of as suction chambers for pumps, affect the degree of purification. Many operators have remedied this problem by cutting storage capacity through the construction of brick walls or concrete fillets, or by shortening the drawdown.

The size of the wet well should be based on the pump capacity. The active storage capacity or draw down should be equal to 1 to 1½ times the pump capacity.

Regardless of the size, shape, and type of wet well, it should be periodically drained, cleaned, and flushed with water under pressure to remove all deposits and floating solids. Grease that congeals on the walls will break loose in large pieces causing the suction line of the pump to clog, or preventing the float from operating.

When a new sewer system or section is put into service, the wet wells frequently receive large quantities of sand with the sewage. This sand should not be pumped out with the sewage pump, but should be removed with buckets as often as inspection indicates the need. If the sand is pumped out with the sewage pumps, the operator can expect earlier maintenance troubles. When effective water seals are not used the sand will get into the stuffing box packing and soon wear out the packing and pump shaft sleeve. On submerged type pumps this causes the lower sleeve bearing to wear out in a few weeks.

### Electrical Control Equipment

Practically every motor is protected by a fused mainline switch and an across-the-line type starter. In addition, float switches and other control equipment may be required to automatically start and stop the motors. The fuses and thermal units used should comply with the National Electric Code or local code recommendations. The fuses and thermal units are generally rated at 125 per cent of the nameplate amperage.

The fused mainline switch and starter protect the motor against "burn out" from short circuits, grounding, high starting current, overload, phase failure, and low or high voltage. When new motors are installed the size of the heating element in the starter should be checked against the current requirements of the motor. A starter with an oversized heating element, or with a "jumper" around the element, does not furnish protection.

If a starter with thermal protection is cutting out frequently, and the trouble cannot be located in the mechanism, location of the starter should be checked. Perhaps it is located too close to a radiator or some other source of heat. In these cases the manufacturers may recommend use of the next size thermal unit.

Every six months, the starters should be checked to make certain the tripping element is not corroded and the motor has protection. All parts should be checked for clearance and freedom of movement. If the contact points are pitted, worn, or arcing, the tips should be renewed or filed smooth, treated with petrolatum, and adjusted or lined up properly. Seriously pitted contact points may burn out the motor if they cause the motor to start and stop too frequently.

When a starter trips out, the cause must be found and corrected before the starter is reset. The following checks will help to locate the trouble:

1. The pump shaft should be turned by hand to see that it is free.
2. Wiring and controls should be inspected for loose connections.
3. Contact points should be checked for wear, pitting, or arcing.
4. Brush-type electric motors need to be checked for sparking while starting or operating, and for sticking brushes.
5. Fuses and thermal overloads should be checked for correct rating.
6. The location of fuses and thermal overload units should be checked with respect to the affect of nearby heat sources.

The switchboard should be inspected frequently and kept clean. Vibration may cause loose terminal connections, when least suspected. The insulators should be wiped clean to prevent flashover to the ground.

Dirty contacts are costly power consumers. An operator of a 0.5-m.g.d. plant was surprised to find a large reduction in his monthly power bill after thoroughly cleaning all contacts, fuses, and fuse holders.

## Motors

Three-phase, squirrel cage motors are widely used in sewage treatment plants. These motors require little attention under average operating conditions. Bearing housings are packed with sufficient grease before leaving the factory to last approximately one year. Too much grease causes bearing trouble, due to excessive friction, or damage to the motor windings caused by excess grease deposits on the insulation.

Horizontal motor bearing housings are equipped with a fitting for adding grease. Excess grease is expelled through a relief plug and thus prevents overloading. Grease should be added to motors while running. It is important that motors run long enough before replacing the relief plug to permit the rotating parts to expel any excess grease. Motor manufacturers recommend that grease be added sparingly when using a pressure gun. Periodic inspection and maintenance is necessary to assure effective lubrication.

Many motors have been damaged by overgreasing. In order to minimize this trouble, some manufacturers have designed motors with pre-lubricated sealed ball bearings and bearing housings without grease fittings. The pre-lubricated ball bearings in general purpose motors have proven satisfactory. These motors can operate 24 hr. per day for five years without greasing. Thus, periodic greasing has been reduced to one grease packing job in five years and overgreasing and grease seepage into windings has been eliminated.

Motors and control equipment installed in damp locations, such as underground pump stations, have been damaged seriously by excessive condensation. The best cure seems to be the installation of a small blower of adequate capacity to change the air as often as necessary to eliminate condensation. Gravity ventilation by means of pipe openings has often proved to be inadequate. Humidity in the control box is best controlled by installation of a dehumidifier or strip heater elements in the box.

It is good practice to blow dust, dirt and other accumulations from motor windings with compressed air. The air should be free of excessive moisture and the pressure should not exceed 80 p.s.i. The frequency will depend on the location and type of motor.

Frequent starting and stopping of electric motors is detrimental. The starting current of a motor is generally several times its full load current, and will store up heat in the windings. A

similar condition is caused by overloaded motors. The excess heat in the windings will bake out the insulation, causing it to become dry and brittle with eventual flaking off and failure.

Where motors are installed in hot locations consideration should be given to the use of oversize motors. These motors, working below maximum capacity would be less likely to seriously heat.

Should a motor be submerged, the bearings should be immediately removed and dried to prevent them from rusting. The motor should be sent to the repair shop for a thorough cleaning, and be baked out before it is put back into service.

For satisfactory electric motor operation, regardless of the type of motor, the following should receive a weekly check:

1. The motor shaft for freedom from oil and grease.
2. The oil level in bearings.
3. The speed and direction of rotation.
4. The commutator and brushes.
5. The tightness of all wiring connections.
6. The interiors and exteriors of the motor for freedom from moisture, oil and dirt.

Semi-annual checks should include:

1. Draining and replacement of the oil in sleeve bearings and gear box.
2. A check of the grease in ball or roller bearings.

The ball or roller bearing housings should be cleaned out and greased annually.

By using these basic maintenance checks on a regular schedule, the heart of the sewage treatment plant will be kept in a serviceable pumping condition.

## TIPS AND QUIPS

### Raindrop Samples

In the atomic-energy field scientists have developed techniques that permit the analysis of samples as small as 10 microliters, an amount considerably less than a raindrop. Basic principle involves the use of electrodes.

Oops! Where is that sample?

### Motorized Wheelbarrow

Since the wheelbarrow was invented by a Frenchman in 1750 it has helped man move his belongings or build structures, but always with some strain on the physique. However, a recently announced motorized wheelbarrow promises to take practically all the strain and work out of what once was "back-breaking" labor.

The "Workhorse" wheelbarrow by the Worthington Mower Company, Stroudsburg, Pa., is reported to handle a 300-lb. load on a 16 per cent grade with ease. Powered with a 2½-hp. gasoline motor and equipped with two drive wheels in front, the unit operates at a walking pace. Steering is done

by means of a guiding caster-wheel in the rear.

## Clean Water and How to Get It

A companion bulletin to the revised film "Clean Waters" has been released by the General Electric Company. This booklet, "Clean Water and How to Get It," presents an outline for anti-pollution programs on the local community level. Interestingly written and illustrated, the bulletin is full of many result-getting suggestions for cooperative action. It not only gives useful facts and information about pollution and modern sewage treatment, but it outlines a suggested course of action for local program promoters. Many examples of ideas that have been successfully used by others to get results are included.

The colored film "Clean Waters" is available from the nearest General Electric sales office or from the General Electric Co., One River Road, Schenectady 5, N. Y. Copies of the "Clean Water" booklet can also be obtained from the same sources. Write for a copy today, you will be glad that you did!

## Time for Spring Planting

Spring is bursting out all over and the local sewage treatment plant should be right in step with its landscaping activities. It is encouraging to note that throughout the country sewage treatment plants are becoming known for activities other than the treatment of sewage.

At the DeKalb, Ill., sewage treatment plant more than 20,200 gladiolus bulbs in 252 choice varieties are planted early in the spring. These bulbs do very well and produce thousands of fine flower spikes, which are admired by hundreds of visitors to the plant. The plant is known locally as the place where beautiful glads are grown. Thousands of flower spikes also are given away and many more are left to bloom in the garden.

In the fall, approximately 31,000 gladiolus bulbs are dug, from which 20,000 of the best bulbs and varieties are selected for spring planting. It is through the constant propagation of the newer and better varieties and the discarding of old inferior ones that this sewage treatment plant has gained the reputation it has.

In addition to the glads, several hundred aster plants are set out early in May to produce a fine array of bloom from early summer until well into the fall. A small greenhouse aids in the starting of seedlings and is a source of interest and pleasure to the staff during the winter.

Fortunate are the communities who have personnel with a "green thumb," but green thumb or not all sewage treatment facilities can do well to give attention to the landscaping of their grounds. The hardy petunia has been displayed to advantage in many an otherwise drab treatment plant. Most sewage treatment plant operators are down-to-earth men and their treatment facilities have the makings of a flower show place. A start on this summer's bloom can be made now, and "green thumbers" are invited to pass their ideas and know-how on to fellow operators through the medium of the Operator's Corner.

## Are Your Records Safe?

All too frequently, maintenance records and fire protection are considered necessary evils until an emergency arises, when fire has frequently destroyed both plant and records.

Last fall one city, with the custom of leaving plans on tables, hung on walls, and the vault door open at night, was visited by fire that destroyed the entire building. Only the corners of manhole and sewer line cards remained in the open vault.

Records worth keeping are worth protecting!

# Editorials

## POLLUTION CONTROL MEANS BETTER HEALTH

The observance of World Health Day on April 7 afforded a further opportunity to arouse throughout the civilized world a greater consciousness of the role which health plays in man's daily life. The theme chosen for World Health Day 1955, "Clean Water Means Better Health," serves both to emphasize the World Health Organization interest in strengthening environmental sanitation and to underline a problem which is causing anxiety to health authorities both at home and abroad.

Clean water for our nation's rivers has been emphasized more since the Water Pollution Control Act of 1948 provided the needed stimulus to motivate communities and citizens to action. Much progress has been made in arousing public interest in the cleaning up and preservation of our waterways.

More and more, cities have awakened to the need for treatment of their waste before discharging it to downstream neighbors. Today nearly 60,000,000 people in the United States are served by approximately 7,000 sewage treatment plants. The managements of these facilities have done an outstanding job in keeping these plants operating efficiently to protect the receiving waters as much as possible. However, an even greater task lies ahead.

Treatment plant construction has not kept pace with our growing population. A record 4,000,000 births in 1954 indicate that we shall face an even greater strain on the ability of some facilities to accommodate the load. In addition, America now enjoys the highest standard of living and the greatest industrialization of any time in its development. Coupled with this economic abundance has come more leisure, an increased interest in recreation, and the use of the natural resources of lakes and rivers. The combination of increased domestic and industrial wastes and a wider public demand to the enjoyment of nature has placed stream sanitation in a critical light.

The need is paramount, and the interest is great. Cooperative action by industry, municipalities, and government, as so well exemplified by the great strides made by various states within their boundaries and through cooperative programs by river basin groups, speaks well for the awareness to the problem. The role of the Federation, through the members of its Member Associations, is important in the promoting and maintaining of this public and individual interest in the needs of today.

As a clearing house for ideas and coordinated action, the Federation can do much to promote the conservation of water resources, one of the principle assets of this nation. Through research stimulus, answers can be found to better sewage treatment at lower cost. Stimulation of the practical solution to the many problems of this radioactive age is vitally needed. As we learn and improve the methods of treating and re-using our water resources we will be contributing much good to the preservation and improvement of the health of the people. But even as we practice what we preach at home, we must not forget to extend a helping hand to those peoples in other lands who need our aid and guidance. The Federation, through its position of leadership in the sewage and industrial wastes field both at home and abroad, can do much to foster the understanding and friendship that is needed.

## FEDERATION OFFICE MOVED TO WASHINGTON, D. C.

By the time this issue is received by the readers, final details will have been arranged for moving the Federation headquarters office from Champaign, Ill., to Washington, D. C., about the end of April 1955. The move is being made in accordance with Board of Control action.

The original location under the part-time secretariat of H. E. Moses was at Harrisburg, Pa. In 1941, when W. H. Wisely became secretary on a part-time basis, the headquarters was moved to the office of the Urbana-Champaign (Ill.) Sanitary District in Urbana, Ill. During this entire period the JOURNAL editorial office was maintained in Chicago, Ill., under the administration of Editor F. W. Mohlman. When the secretarial and editorial functions were combined on a full-time basis in 1944, the quarters at 325 Illinois Building, Champaign, Ill., were leased and occupied.

The new location in Washington provides ample space for present Federation headquarters activities and foreseeable staff requirements. The new address is:

Federation of Sewage and Industrial Wastes Associations
4435 Wisconsin Avenue, N.W.
Washington 16, D. C.

All those interested in Federation activities are invited to visit the new quarters at any time.

# Book Reviews

**Standard Methods for the Examination of Water, Sewage and Industrial Wastes.** By Committees of APHA, AWWA and FSIWA. Amer. Pub. Health Assn., 1790 Broadway, New York 19, N. Y. 522 pp. Price, $7.50 (1955).

In this standard work prepared jointly by the American Public Health Association, the American Water Works Association and the Federation of Sewage and Industrial Wastes Associations, practically every method has been drastically revised to include up-to-date methods, technics and materials. Particular attention has been given to the use of spectrophotometric and photometric procedures. The organization of the text has been greatly improved and the typography has been designed for greater ease in locating desired information. The changes and additions in this Tenth Edition are the largest to be noted in any revision, the text length being almost doubled over the Ninth Edition.

The volume is divided into six parts, as follows:

Part I—Chemical Methods for Water

Part II—Examination of Sewage

Part III—Industrial Wastes

Part IV—Examination of Bottom Sludges and Mud

Part V—Bacteriological Methods

Part VI—Microscopic Methods

Additions include:

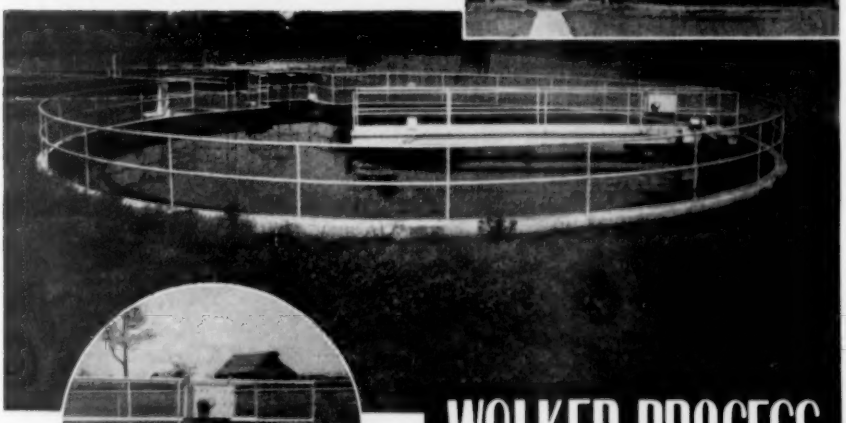
1. Discussion of correctness of analysis, precision and accuracy.
2. Review of statistics for analysts.
3. Nomograph for alkalinity and carbon dioxide.
4. Compleximetric EDTA titration method for hardness.
5. Spectrophotometric and photometric methods for color.
6. Essentially a new procedure for cyanides.
7. Membrane filter technic.
8. Twelve full-page figures showing typical plankton and bottom-dwelling organisms.
9. Parts I, II, III and IV arranged fully in alphabetical order.

For anyone engaged in the water, sewage or industrial wastes fields this book is an absolute "must." H. P. O.

**A Treatise on Applied Hydraulics.** Fourth Edition. By Herbert Addison. John Wiley & Sons, Inc., New York, N. Y. 724 pp. Price, $9.50 (1954).

This general hydraulics text limits itself to direct explanations of hydraulic principles while serving as a guide to sources where more detailed information may be found. With its careful revision of the subject matter to include the widened horizon of the field it covers, this fourth edition epitomizes the author's experience in the lecture room and the laboratory during 30 years of instruction and research. H. P. O.

# Farmington, Mo. Sewage Disposal Plant uses...



## WALKER PROCESS

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Tractor Drive Circular Collector mechanisms are installed in both the 44′ diameter primary and 38′ diameter final settling tanks. These rugged units feature a unique simplified tractor arrangement, providing rotational force at the tank periphery.

A four-arm 10″ H Rotoseal rotary distributor delivers 1570 gpm over the 120′ filter bed. A mechanical Neoprene seal and large cast bronze lower thrust bearing add to the trouble-free operation of this unit.

The 39′ diameter Floating Cover on the digester is designed so that no truss or frame work protrudes above the tank. Constant gas pressure is maintained. Ballast and counter weights are suspended below the cover as positive prevention against overturning.

The Walker Process HeatX accomplishes sludge heating outside the digester. This self contained unit includes control panel, burner, hot water tube boiler and shell, and tube exchanger. It operates on natural and sewage gas.

| | |
|---|---|
| Consulting Engineer: | Charles A. Haskins<br>Kansas City, Mo. |
| Superintendent: | Frank Zimmer |
| Chief Operator: | Otha Parker |

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# Proceedings of Member Associations

## FLORIDA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 1954 Annual Meeting of the Florida Sewage and Industrial Wastes Association was held at the Soreno Hotel, St. Petersburg, Fla., on November 7–10, 1954, jointly with the Florida Section, AWWA. Registration totaled 305, including 83 ladies.

Among the highlights of the program were panel and forum discussions on industrial waste odors, citrus industry wastes treatment, grit chambers and sewage lift stations. Other papers included the following:

"Financing Water and Sewer Systems," by Ross E. Windom, City Manager, St. Petersburg.

"Legal Implications of Stream Pollution," by George E. Owen, Assistant Attorney General, State of Florida.

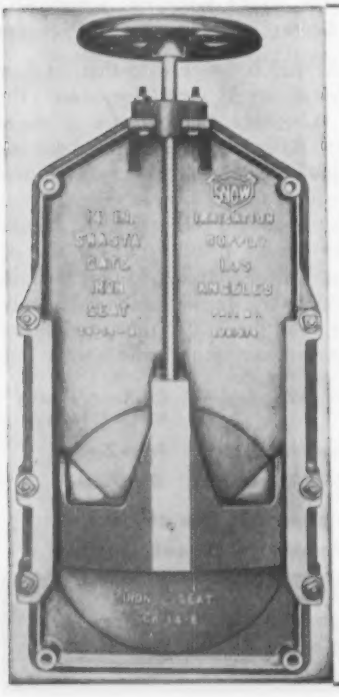
"Problems in Selecting a Paper Mill Site at an Inland Location," by W. T. Webster, Vice-President, National Container Corp., Jacksonville.

"Laws of Florida Governing Water Use," by Frank E. Maloney, Professor of Law, University of Florida, Gainesville.

"The Red Tide of the Florida Gulf Coast," by Professor James B. Lackey and Jacqueline A. Hynes, College of Engineering, University of Florida, Gainesville.

"The Catalytic Reduction Process," by T. H. Forrest, Chicago Pump Co., Chicago, Ill.

(*Continued on page 158a*)



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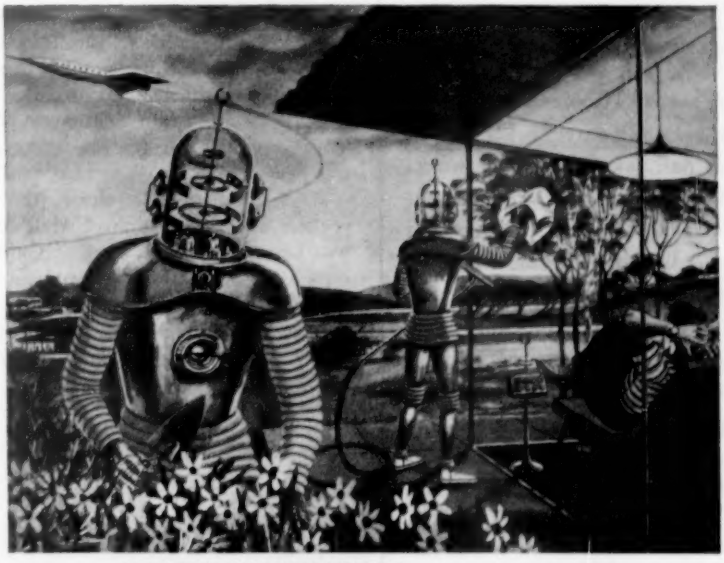

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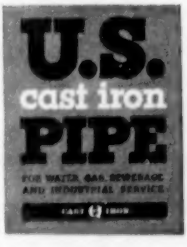


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## POSITION AVAILABLE

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For trade association work in sewage and water fields. Must have had sewage or water works experience; able to write papers, to attend technical meetings and take part therein; answer technical correspondence. If interested give record of experience, also record of technical papers; and state starting salary desired. Reply to Box C, Sewage and Industrial Wastes, 4435 Wisconsin Ave., N. W., Washington 16, D. C.


"Biological Studies in Stream Pollution," by W. M. Beck, Jr., Biologist, Florida State Board of Health, Jacksonville.

"St. Petersburg's Sanitary Sewerage Problem," by W. W. Gillespie, Consulting Engineer, Jacksonville.

The Federation's Arthur Sidney Bedell Award was presented to John W. Wakefield.

Inspection trips were made to St. Petersburg's new municipal water and sewage treatment plants.

Officers elected for 1955 were as follows:

*President:* P. Flanagan, Tampa.
*Vice-President:* C. E. Richheimer, Jacksonville.
*Secretary-Treasurer:* M. E. Dawkins, Jacksonville.

M. E. DAWKINS,
*Secretary-Treasurer*

## ROCKY MOUNTAIN SEWAGE WORKS ASSOCIATION

The 18th Annual Meeting of the Rocky Mountain Sewage Works Association was held at the Broodmoor Hotel, Colorado Springs, Colo., on November 8–10, 1954, in conjunction with the Rocky Mountain Section, AWWA. Total registration for the dual meeting was 139.

At the business luncheon, the Federation's Arthur Sidney Bedell Award was presented to Charles G. Caldwell, New Mexico State Department of Health. Also, steps were taken to change the name of the Association to Rocky Mountain Sewage and Industrial Wastes Association, and to include Utah in the Association area.

Officers were elected as follows:

*President:* W. F. Turney, Sante Fe, N. Mex.
*Vice-President:* R. L. Streeter, Casper, Wyo.
*FSIWA Director:* B. V. Howe, Denver, Colo.
*Secretary-Treasurer:* J. R. Peterson, Denver, Colo.

Technical papers presented included the following:

"New Design Standards for Sewage Treatment Plants," by W. N. Gahr, Director of Sanitation, State Dept. of Public Health, Colorado.

"Biological Additives in Waste Treatment," by A. J. Krell, Technical Director, Reliance Chemical Corp., Houston, Tex.

"Sewage Lagoon or Oxidation Ponds," a panel discussion.

"Neglected Fields of Industrial Wastes," by a panel comprising equipment manufacturers' representatives.

"Sewer Joint Materials," by Don Lacy, District Engineer, Clay Products Assn., Chicago, Ill.

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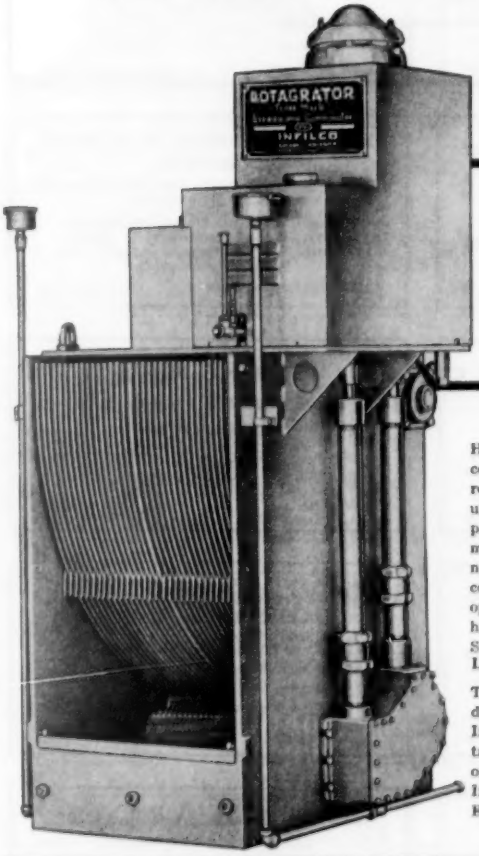


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## INDEX TO ADVERTISERS


| | Page |
|---|---|
| Beckman, Arnold O., Incorporated | 144a |
| Builders-Providence, Incorporated (B-I-P Industries, Inc.) | 131a |
| Cast Iron Pipe Research Association | 134a, 137a |
| Chain Belt Company | 129a |
| Chapman Valve Manufacturing Company | 169a |
| Chicago Pump Company | 129a |
| Combustion Engineering, Incorporated (Raymond Division) | 142a |
| Dorr-Oliver Incorporated | 154a |
| Fischer and Porter Company | 130a |
| Flexible Sales Corporation | 166a |
| Inertol Co., Inc. | 148a |
| Infilco Incorporated | 139a |
| Johns-Manville Corporation | 140a, 141a |
| Link-Belt Company | 143a |
| Morse Boulger Destructor Company | 144a |
| Nichols Engineering and Research Corporation | 151a |
| Pacific Flush Tank Company | 152a |
| Rockwell Manufacturing Company (Hersthrom Valve Division) | 146a |
| Simplex Valve and Meter Company | 133a |
| Snow Gates and Valves | 156a |
| United States Pipe and Foundry Company | 157a |
| Vapor Recovery Systems Company | 158a |
| Walker Process Equipment, Incorporated | 155a |
| Wallace and Tiernan Company, Incorporated | Back Cover |
| Worthington Corporation (Pulsfo Works Division) | 147a |
| Yeomans Brothers Company | 135a |


## DIRECTORY OF ENGINEERS, pp. 160a–248a

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